COMBUSTION

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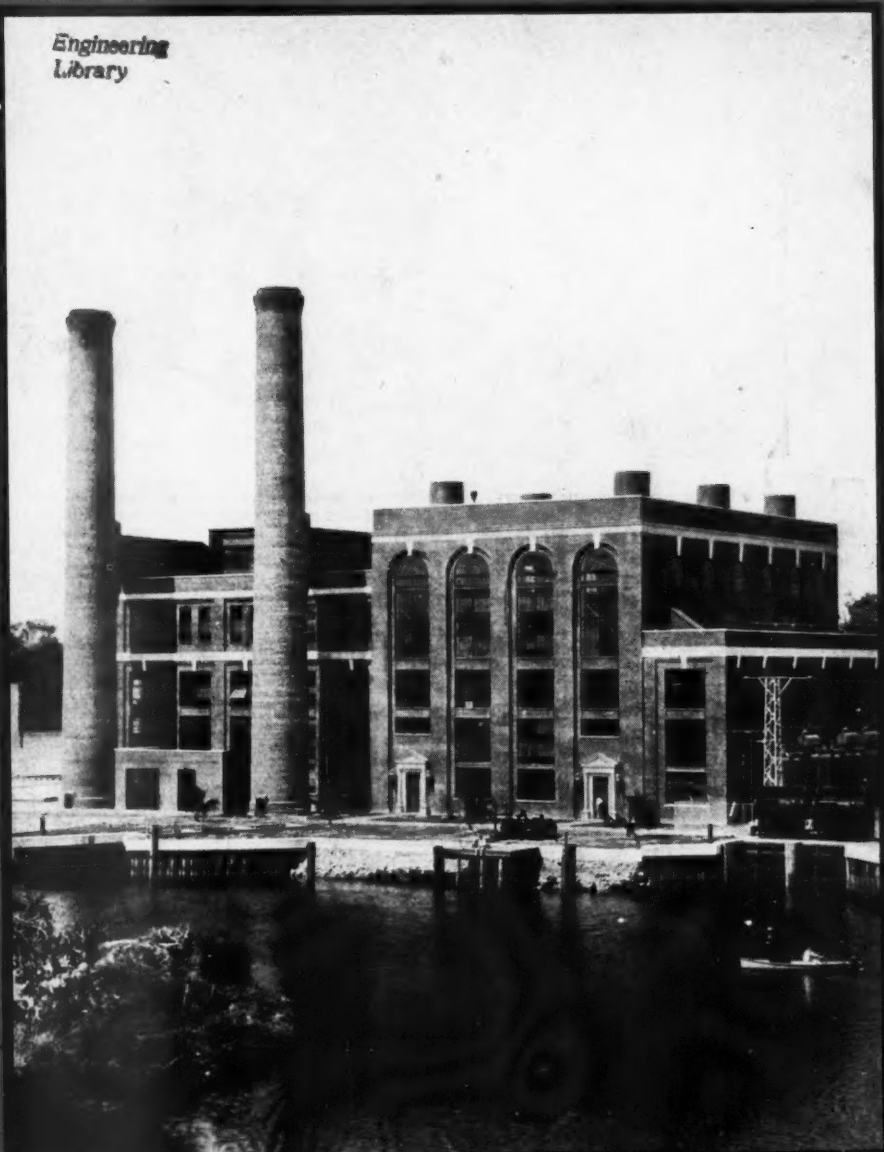

INGLIS PLANT, FLORIDA POWER CORPORATION, ST. PETERSBURG, FLA.

Central Steam Heating Plant Effects Remarkable Economies

By A. M. DODDS

Design and Selection of Burners for Pulverized Fuel, Oil and Gas

By J. B. RICE

OTHER ARTICLES IN THIS ISSUE BY

JOHN J. GREBE • L. C. WINSHIP • DAVID BROWNLIE • F. B. DOANE • LESLIE CHILDS

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COMBUSTION

VOLUME 3 NOVEMBER 1931 NUMBER 5

Science to the Aid of a Sick Industry

THOMAS S. BAKER

THE idea back of the Third International Conference on Bituminous Coal to be held at Carnegie Institute of Technology next November is the hope that we shall find new uses for bituminous coal. As the scientists present their papers covering new processes, discoveries and uses of the various derivatives of coal, it is our expectation to point out the application of these discoveries, what they will mean as possible new outlets for our surplus coal. This basic industry in its present state of acute depression needs help from many quarters, and it is our belief that science may be of assistance in directing it on the road to recovery.

But while the conference is primarily scientific and will include papers on the carbonization, liquefaction and gasification of coal, by-products, the mechanism of combustion, the cleaning of coal, and its preparation for the market, pulverized fuel, power plants and related subjects, yet the economic problems will also have a place in the discussions.

If a rational method could be evolved of dealing with our vast fuel resources—coal, petroleum and natural gas—we should go a long way towards relieving the present business crisis. Our prime object in considering at our conference the manifold new uses of distillation that are being developed all over the world is to discover new ways for utilizing the excess of coal production; but a still greater problem confronts the coal industry, namely the finding of some feasible method of restricting production and avoiding ruinous competition.

The main purpose of the immense amount of research being carried on in this field is to secure a greater value for coal. On a tour through Europe recently I found that the most interesting and extensive work is being done in Germany. In spite of the political unrest and lamentable economic situation, laboratories with most efficient staffs and equipment are proceeding patiently with their studies whose prime purpose is to get more out of coal realizing that in this way the value of coal can be increased. Germany is sending to our congress next November men like Franz Fischer, Rosin, Bergius, Berl and Terres.

In England, valuable work is being done at the government station at Greenwich under the direction of Dr. Cecil Lander, at many of the universities and especially in the research laboratories of the Imperial Chemical Industries Company. We shall have a large and distinguished delegation from Great Britain in November.

In France, coal research is not so concentrated as in Germany or in England. The French delegation has not yet been decided upon, but it is expected that there will be representatives from the department of mines and from many industrial and academic laboratories. We have also had assurances that Spain, Belgium, Poland, Holland, Austria, Czechoslovakia, Yugoslavia, the Scandinavian countries and Japan will be represented in Pittsburgh.

Thomas S. Baker

President, Carnegie Institute of Technology
Chairman, International Bituminous Coal Conference

E D I T O R I A L

Third International Bituminous Coal Conference

IN the feature editorial in this issue, "Science to the Aid of a Sick Industry," Dr. Thomas S. Baker strikes the keynote of the Third International Conference on Bituminous Coal, which is to extend the use of bituminous coal both through the development of new outlets for its numerous derivatives and the improvement of the product itself for use as a fuel.

The extension of the use of coal derivatives is a broad field having correspondingly broad commercial possibilities but development along this line is likely to proceed slowly. Nevertheless, it should be pursued vigorously as in the course of a decade it may entirely change the economic structure of the industry. The many valuable papers to be presented on this aspect of the coal problem will serve to correlate a vast amount of isolated knowledge and will thus serve to guide and facilitate further development.

The papers and discussion on the use of raw coal as a fuel have perhaps a greater immediate value to the industry in these days when the challenge of other fuels has already seriously affected the demand for and the price of coal. Meeting this situation requires a fundamental change in policy on the part of coal producers. Today coal must be sold as a manufactured product, prepared by the producers to meet the specifications of consumers. Much work is being done on the classification of coal in order that the buyer may select with confidence a coal that is properly suited to his requirements and that can be depended upon to produce uniform results. The organization of this work began at the First International Bituminous Coal Conference in 1926. At that time a committee, known as the Sectional Committee on Coal Classification, was formed under the sponsorship of the American Society for Testing Materials and proceeding in accordance with the rules of the American Standards Association. This Committee and its several sub-committees are representative of the various groups concerned with the problem and real progress is being made in the development of a rational and comprehensive system of classification which should be of great benefit to coal producers as well as coal consumers.

As an example of the advantages attending the preparation of coal in order to meet specified standards the following facts were brought out in a paper, "Growth of Coal Preparation in the Smokeless Fields of West Virginia" prepared for the American Institute of Mining and Metallurgical Engineers by T. W. Guy. The writer shows that, since the first washer was installed in 1903 in the Pocahontas field, the movement for cleaning coal has increased until now 73 plants of 54 different companies have mechanical cleaning operations of several different types. These 73 plants produced about 42½ per cent of the total output of the smokeless fields in 1930. Furthermore, even in 1930 with its markedly decreased production of bituminous coal, the companies producing washed coal were affected less by the depression than were other plants of the smokeless field. Moreover, groups of mines that cleaned all of their coal showed less decreased production in 1930 than groups that cleaned only part of their output.

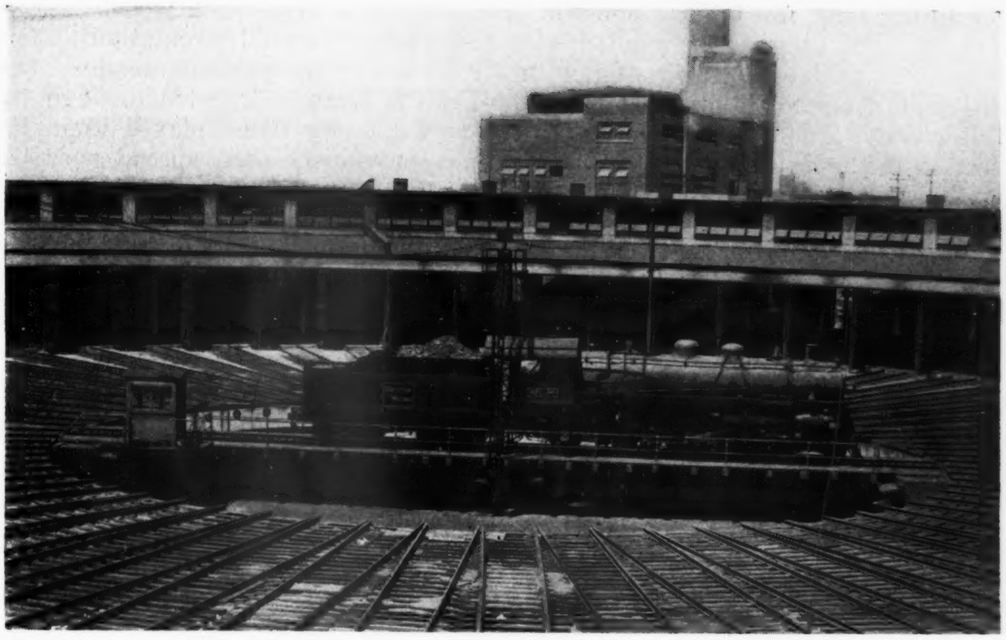
Tangible Results—The Engineer's Heritage

THERE is something gratifying and encouraging about the process of applying an exact measure to one's efforts and securing an exact answer; an answer that is indisputable. All of us have an instinctive desire to be able to see the effect of our work and to know the extent to which that effect is due to our own effort. Executives can see results in terms of profits and they can conclude that such profits are the result of certain definite factors but it is difficult, if not impossible, to determine the exact extent to which each of these factors contributes to the total result.

The writer produces a new book which meets with a large sale. If he is analytically minded, he may try to discover the secret of the success of his effort, perhaps in the desire to adduce a formula or principle which can be taken into account in his later writings. But how much of the success of this book was due to the impression made by his earlier writings, how much to the merchandising and publicity work of his publishers, how much to fortuitous circumstance?

Outside of the scientific field, this natural instinct to measure accurately can but rarely be applied except in a broad general sense. How fortunate then is the engineer who whether he be designer, operator or consultant can apply the yardstick of exact measurement and determine within small limits of accuracy the results of his work.

The steam plant engineer with the aid of the instruments at his disposal may determine the efficiency of the various processes and operations under his control, may calculate the savings that can be effected by the use of improved equipment and can thus place his superiors in a position to determine when and where capital expenditures are justifiable. In short, he can give to his work a matter-of-fact interpretation that should engender those qualities of self-confidence and purposefulness so essential to success in any field of activity.



Part of the enginehouse and turntable circle of new Boston Terminal with the power plant in the background. Smoke jacks are omitted from the roof of the section to the left.

Direct Steaming Effects Fuel Economy and Increases Locomotive Availability

By L. C. WINSHIP
Electrical Engineer
Boston & Maine Railroad

A discussion of direct steaming of locomotives based on the experiences of the Texas & Pacific Railway Company was given by Paul E. Roll in the December, 1930, issue of COMBUSTION. The present article describes the direct steaming installation at the new Boston Terminal of the Boston and Maine Railroad. This terminal, designed for 100 departures in twenty-four hours, is now despatching between 130 and 150 locomotives a day, a performance which is made possible principally through the increase in locomotive availability resulting from direct steaming. There are many other advantages, including a substantial saving in fuel.

THE Boston and Maine Railroad, in accordance with its policy of maintaining the highest possible efficiency in the economical handling of equipment, has incorporated in its new Boston locomotive terminal one of the newer facilities known as "direct steaming."

Among the things hitherto unattained which are now possible through the use of this facility are a material decrease in terminal smoke production, a clean enginehouse free from smoke, noise and vapor, an increased utilization of locomotives through quicker handling of repairs, a reduction in boiler maintenance costs through decreased concentrations of boiler water and an over-all decrease in fuel consumption.

Direct steaming is essentially the maintenance of steam pressures in a locomotive boiler with no fire on the grates. The steam required is supplied from an outside source and is so regulated as to maintain a predetermined reduced pressure, usually referred to as the floating pressure, in the locomotive over an indefinite period with the possibility of quickly raising this pressure to an operating value for the movement of the locomotive across the turntable to the fire starting station.

The equipment required for direct steaming is so intimately connected with that designed for the washing and filling of locomotive boilers that the operation can perhaps be more readily visualized with a description of the complete apparatus.

In the washing and filling of locomotive boilers, water and steam from the boiler are blown back by the pressure in the boiler to the power plant, where a separator diverts the water to the washing storage tank and passes the steam through a condenser where it mixes with clean cold water and passes

at high temperature to the filling tank for filling purposes.

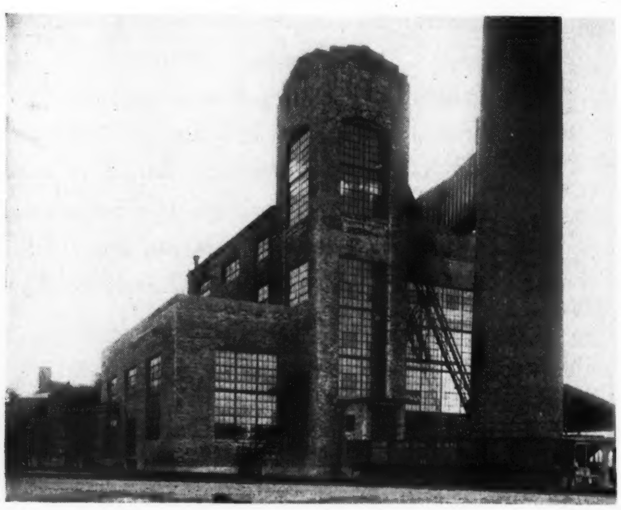
That this filling water may be as free of dissolved oxygen as is practicable, a deaerator is provided through which the filling water is continually circulated. The heating section in the deaerator is supplied with exhaust from the main exhaust header and a water ejector removes the oxygen which separates from the water. The water entering the deaerator is at about 180 deg. fahr. and there is a slight rise in temperature as it passes through the deaerator back to the filling tank.

Blow-back, washing and filling lines extend throughout the enginehouse, and reciprocating pumps, automatically controlled in the power plant, maintain pressure continually in both the washing and filling mains.

Adjacent to the blow-back and filling mains in the enginehouse, is the direct steaming line, and a single down-comer serves the three lines. This down-comer is a vertically suspended pipe carrying at its lower end two sections fitted with ball and socket joints which provide an easy connection with the blow-off valve of the locomotive. Two connections with the direct steaming line are provided, one of ½ in. dia. being used for floating the locomotive at reduced pressure—the other of 2 in. dia. being used to boost the pressure to operating values.

The washing and filling system at the Boston terminal serves only the fifty pits in the enginehouse. The direct steaming lines are further extended to include ten locomotive locations on adjacent tracks outside of the house, thus providing a total of sixty direct steaming locations.

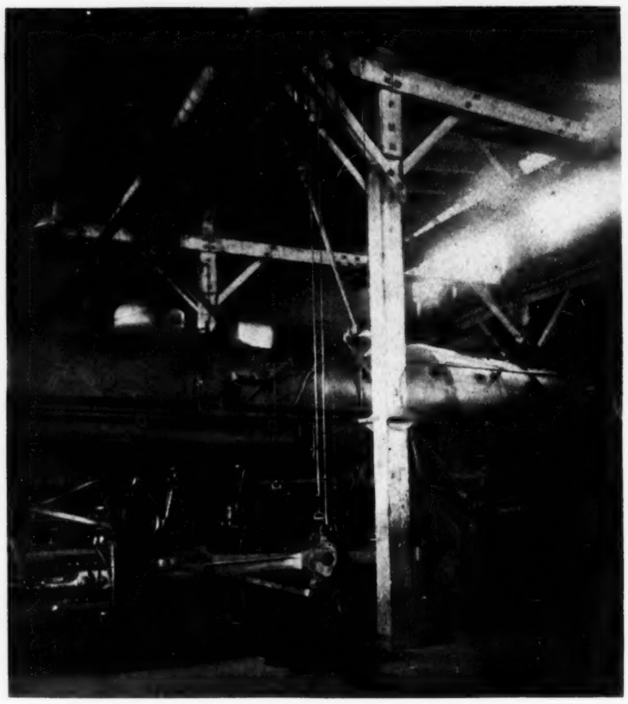
Water temperatures of approximately 130 deg. fahr. and 185 deg. fahr. are maintained in the



Power plant with the locomotive boiler filling and washing tanks at the left.

washing and filling lines respectively. The direct steaming line carries steam at 220 lb. pressure with 100 deg. of superheat.

Fire starting stations, which are a necessary adjunct to direct steaming, are located on four of the outgoing tracks. The equipment at these stations consists primarily of a large torch which is supplied with fuel oil from an oil circulation system and with air from the compressed air lines. In starting the fire the torch is inserted through the firebox door and a heavy flame played upon the coal which has previously been spread over the



A unit of direct steaming equipment with the down-comer connected to a large freight locomotive.

grates. Proper ignition of the fuel is obtained in from eight to twelve minutes and the locomotive is then ready for departure.

The locomotives which are to be held at the terminal for approximately six hours or longer come in from the road with the fires practically out so that there is a minimum waste of fuel through the dumping of the fire at the ashpit. After the fire is dumped and the engine washed it moves across the table to the house location under its own power, arriving with steam at about 100 lb. pressure. The connection with the down-comer is made immediately and the floating valve opened.

Theoretically, this locomotive would continue to receive steam through the floating valve with a maintained pressure of about 100 lb. under the supervision of the direct steaming attendant. At such time as the condensation reached the top of the gage glass, the floating valve would be closed and the blow-back valve opened and this accumulation would return to the power plant, after which the floating valve would be again opened. Shortly before leaving time, the floating valve would be closed and the boosting valve opened and the pressure built up to between 150 and 175 lb., which would be sufficient to take the locomotive out over the table to the fire kindling station where the fire would be started and the engine despatched.

In practice, however, this cycle is not so simple. Shortly after the arrival of the locomotive in the

house, the air brake inspector begins his work. If there is insufficient pressure in the boiler for the operation of the pumps and other brake equipment, the inspector immediately increases the pressure by opening the boosting valve. At the completion of the work the floating condition is restored but the extra boost results in a continued floating period at a higher pressure than that contemplated. While the higher floating pressure may decrease the time required for the final boost, the overall heat loss is much greater and the maximum return is not experienced. As the smaller locomotives will normally show a rise in pressure while floating, very careful attention is required to keep the floating pressure within desired limits.

A locomotive which is due for washout is either blown-back immediately on arrival or held floating until the washout force is ready to begin work. After the water and steam have been returned to the plant, a hose is connected to the washout line and the boiler thoroughly washed with hot water. At the completion of such repairs as may accompany the washout operation the boiler is made ready for filling. Steam is then first admitted through the boosting valve for about two minutes to warm up the boiler shell. This valve is then closed and the one in the filling line opened. As the water begins to flow into the boiler the large steam valve is again opened and the steam and water mix as they enter the boiler. When water appears at the gage-glass drain the valve in the filling line is closed and the steam continues to flow until the desired pressure has been attained. The boiler of a large passenger locomotive can be filled with water in about twelve minutes, and a pressure of 150 lb. can be built up within forty-five minutes after the filling operation has started, with a saving in time of from one to two hours over the previous methods.

While under former conditions firebox and front end repairs were often started with the boiler under pressure, this pressure gradually decreased with the possibility that at the completion of the work there might be no pressure whatsoever. Today, work of this description can be done with no decrease in boiler pressure and if necessary, the locomotive can be ready to move under its own power at the completion of the repair.

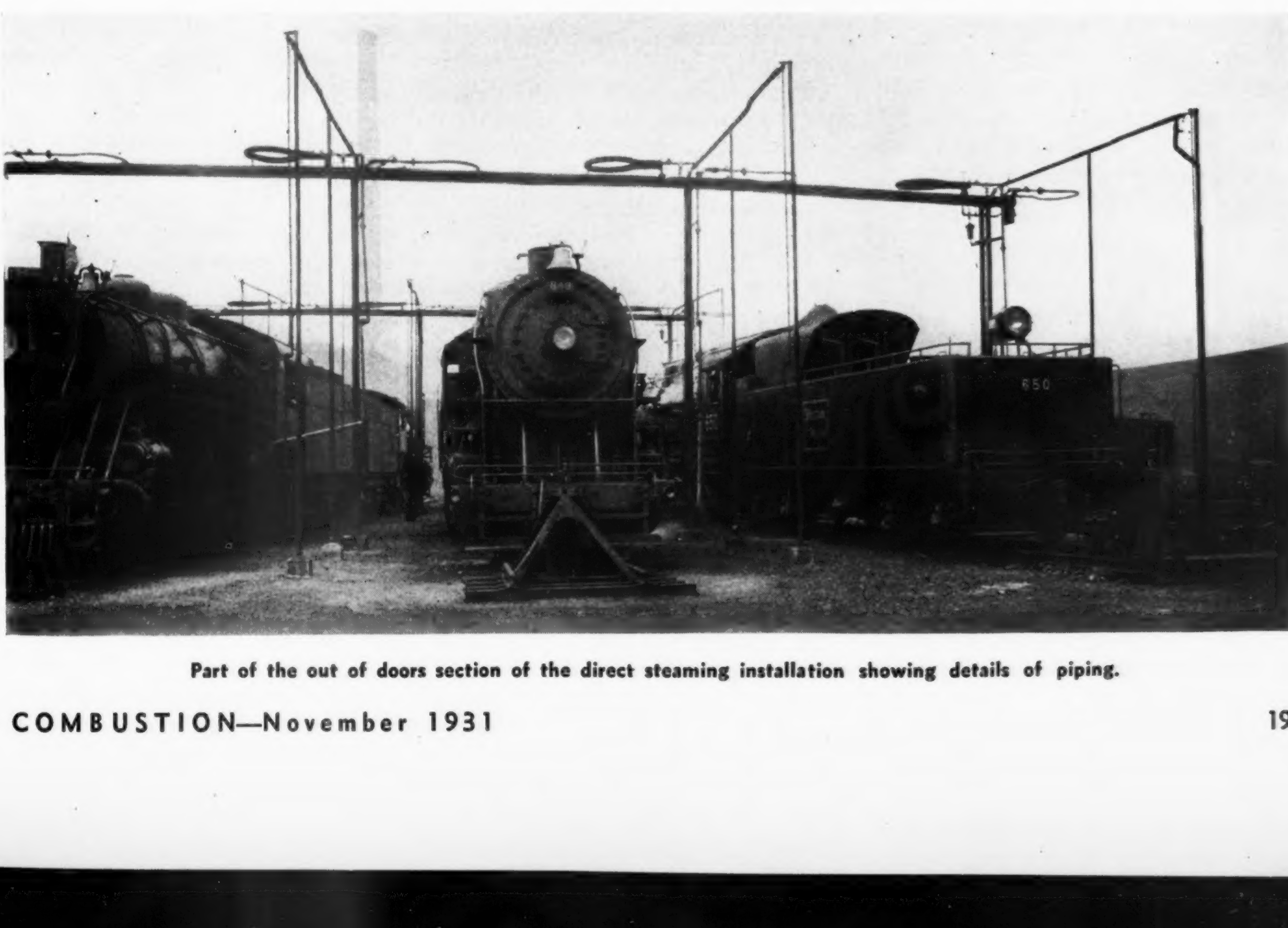
The increase in locomotive availability through the shortening of the time required for these operations is a very important factor in reducing outage losses.

Locomotives which are floated for six or eight hours accumulate sufficient condensation to require a blow-back for a reduction in water level. These tend to reduce the concentrations in the water, which normally increase during the monthly interval between washouts, with a tendency towards the production of scale and a deterioration of boiler plates. While the water in New England is such as to produce a minimum of trouble, the blow-backs given locomotives regularly held on direct steaming do reduce the scale accumulation and retard corrosion.

Locomotives as they reach the terminal, fall naturally into two groups. One includes those which on account of short runs and short terminal lay-over require but little time in the enginehouse for inspection and repair. The other is made up of the heavier power used on the longer runs, which require more work and which are scheduled for longer lay-over periods.

In spite of the fact that the enginehouse is one of the largest in the country, the number of locomotives in the first group, which are cared for during the busier intervals of the day, is so great that house space is not available for a long enough period to make it practical to place these locomotives on direct steaming. Consequently, smoke

(*Continued on page 27*)



Part of the out of doors section of the direct steaming installation showing details of piping.

Design and Selection of Burners for Pulverized Fuel, Oil and Gas

PART II

By J. B. RICE

Various burner arrangements and their fields of application were discussed in Part I of this article, published in the September issue of COMBUSTION. It brought out the fact that no single burner arrangement can be universally used. It further indicated that there are definite limitations on burner operation, resulting from characteristics of associated equipment, which can in no way be overcome by special attention to burner design or by extensive alterations to burners after installation. In Part II the author considers some of the factors intimately involved in burner operation and endeavors to outline the principles of burner design.

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PART I of this article brought out that selection of burners depends chiefly on the type of fuel (present and future), the type and size of fuel preparation equipment, and the total capacity of the unit. Other factors are the range of boiler rating expected, peak load and standby requirements, the combustion rate and efficiency required, furnace proportions and construction, draft equipment, air temperatures, boiler room layout, and previous experience of purchaser and manufacturer.

A detailed study of burners may not seem worth while to men not employed in designing them, but many men who devote their time to associated equipment or who operate plants, often have problems which cannot and are not properly decided if a fundamental knowledge of burners is lacking. Burners amount to a negligible fraction of the cost of a plant, yet as one manufacturer advertises: "They are the bottleneck through which the entire fuel investment passes." An increase of only 1 per cent in efficiency by using good burners saves the entire cost of the most expensive burners in a year.

Some Fuel Characteristics Affecting Burners

Sometimes an "all purpose burner" has been asked for. This is an impossibility. The volumes of gaseous fuels and of air-borne pulverized fuels are variable, compared to the total volumes of air plus fuel. It is obvious from Table 1 that a fuel nozzle cannot be used for more than one fuel when

TABLE I.—RATIO OF FUEL STREAM VOLUME TO TOTAL VOLUME OF FUEL AND CONTROLLED AIR

(The range given for each type of fuel takes care of variations in heating value, feeding system, furnace leakage, excess air, and temperature of fuel and air. Only maximum load conditions are assumed, because these determine burner proportions.)

Pulverized fuel	5 to 50 per cent
Blast furnace gas	40 to 60 per cent
Coke oven gas	10 to 20 per cent
Natural gas	5 to 10 per cent
Refinery waste gas	3 to 7 per cent
Fuel oil	Negligible

it is realized that the richest fuels should have the highest velocities.

Not even the volume ratio for one type of fuel is a fixed quantity. For gaseous fuels the most important variable is the temperature of the air. For pulverized fuels also this is important, but the heating value of the fuel and the amount of primary air required by the feeding or milling system are equally important as shown in Table II.

The tendency of fuel to coke places limitations on burner design. Some pulverized and liquid fuels build up coke on a burner outlet if allowed to impinge on it. Coke will build up inside atomizers of oil burners, if they become too hot. With some coals the primary air temperature is limited to 400, 500 or 600 deg. by the tendency of the fuel to gum up or coke on the feed pipes and nozzles. Burners having nozzles which are rather exposed to furnace heat will accumulate coke deposits unless the primary air is kept below 200 deg. Gaseous fuels do not form coke but they may carry tar or wet dust which may be equally bothersome.

The volatile and ash contents of coal, pitch and coke, or the flash and fire points of fuel oil have important influence on operation. This will be discussed later in connection with the fineness of pulverized fuel and the propagation of flames.

The presence of moisture in any fuel causes difficulties. In liquid fuel it interferes with atomization. In extreme cases it will extinguish the fire. In blast furnace gas it cakes any dust which may

TABLE II.—RATIO OF FUEL STREAM VOLUME TO TOTAL VOLUME OF CONTROLLED AIR AND FUEL FOR VARIOUS CONDITIONS WITH PULVERIZED FUEL

(Assumed data were selected to give the extremes of what might be expected in the usual types of plants at maximum loads.)

Fuel	CO_2	Portion of total air controlled	Primary air	Volume ratio for 100 deg. fahr. Secondary air	Volume ratio for 400 deg. fahr. Secondary air
14,000 B.t.u.	12 per cent	85 per cent	1.2 lb. per lb. @ 130 deg. fahr.	9 per cent	6 per cent
14,000 B.t.u.	15 per cent	70 per cent	3.0 lb. per lb. @ 210 deg. fahr.	37 per cent	28 per cent
9,000 B.t.u.	11 per cent	85 per cent	1.2 lb. per lb. @ 130 deg. fahr.	13 per cent	9 per cent
9,000 B.t.u.	14 per cent	70 per cent	3.0 lb. per lb. @ 210 deg. fahr.	52 per cent	41 per cent

be present into a cement deposit all over the inside of the burner. This makes the weekly, daily, or semi-daily cleaning a very laborious process. In pulverized fuel it increases the tendency for the fuel particles to adhere to each other and to the walls of feed pipes and nozzles. This must be provided against in the design of adjustable nozzles. In extreme cases the nozzles or feed pipes become plugged, especially if they have any horizontal portions. If damp coal from a feeder has not been violently agitated by turbulent primary air many small particles will cling together. If this happens with coking coal (at times when primary air is deficient) the clusters coke into the equivalent of coarse coal, resulting in slow ignition, prolonged burning and high carbon losses.

Pulverized or liquid fuels must not only be ground or atomized to small particles—a major fraction must be broken down to microscopic size in order to insure quick ignition and complete combustion. The extreme smallness of the average particle is seldom realized. Even particles as fine as sand could hardly be expected to ignite in the 1/25 to 1/100 of a second or less which is all that is allowable for steady ignition of a stream moving at 50 to 150 ft. per sec., especially when this ignition is almost entirely by radiant heat. Fig. 1 shows typical fineness curves for pulverized fuel, and for comparison a similar curve for crushed coal (an average of five closely similar samples of crushed run of mine New River coal). The latter (Curve A) has been included because it resembles the others on the logarithmic scale used, and so permits visual realization of the distribution of particle size. With pulverized fuel this can only be obtained with a microscope.

If one looks at damp crushed coal, the coarser particles are seen to have smaller ones adhering to them, and these in turn are covered by still smaller ones. If some of the smallest visible particles are removed, then dried and screened, it will be found that they also have been carrying an appreciable amount of still finer dust. Now a 3/8 in. particle is seen on Fig. 1 to represent the same fraction of the total sample that a 100 mesh particle .0058 of an inch in size represents in an average pulverized fuel (Curve D). The microscope shows that a 100 mesh particle is surrounded by successively smaller particles in the same way as that described above. The smallest ones cannot be counted under a microscope. They are less than 0.00001 of an inch in size, and approach molecular dimensions. An interesting discussion of this is contained in United States Bureau of Mines Bulletin No. 237 by Henry Kreisinger and others.

It is these invisibly small particles in pulverized fuel which ignite first. They also are responsible for the troublesome cementing tendency of pulverized fuel in crevices, etc. The larger particles are lighted from their flames. If there are too many large particles they shield the small ones from radiant heat, so ignition is delayed. Moreover, the

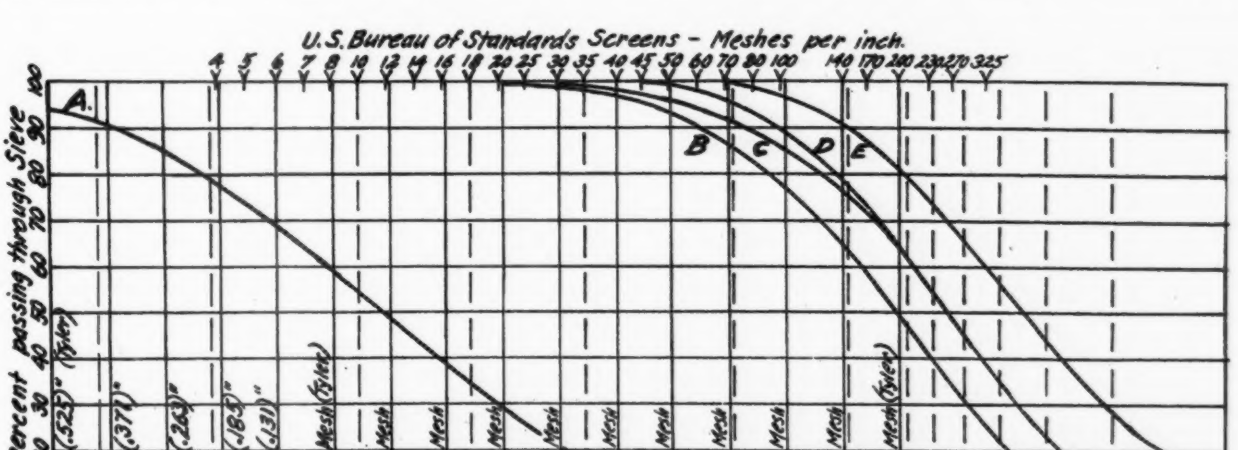

Fig. 1—Typical fineness curves for pulverized fuel.

large ones take so long to burn (they only have a few seconds in a furnace) that their combustion is not completed before they are extinguished among the boiler tubes.

Curve E represents very fine fuel, such as that used in obtaining high temperatures for metallurgical work. It also represents pulverized anthracite. Curve D represents the average pulverized fuel now used in boiler furnaces. Curve C, blending into Curve D represents a poorly classified fuel from an improperly designed or operated pulverizer. It would contain enough fines to ignite readily, but the high content of coarse particles would increase carbon losses by several per cent over those which Curve D would make. Curve B represents well classified, but coarse coal from an improperly adjusted pulverizer. It does not contain enough fines to ignite readily, and combustion of the larger percentage of coarse particles would be slower than is permissible with present day furnaces.

It should not be assumed that all coals, or pitch or coke from any mill will have the exact distribution of particle size shown on Curves B, D or E. The upper end of the curve will vary somewhat. Mills without classifiers will at best give curves having a shape midway between C and D. Adjustments of most mills, to give finer coal without alterations, will not reduce the coarse particles in proportion to the 200 mesh particles, so an increase from 65 per cent through 200 mesh to 80 per cent would still leave some plus 50 particles. As for the lower ends of the curves, not enough microscopic analyses are available to provide really representative averages, but in all cases the general shape of the curves is as shown in Fig. 1. This shape is unavoidable unless fuel is screened, washed, or passed through several classifiers in series, which would of course be impractical for boiler fuel.

The Functions of a Burner

A burner has several functions to perform. First it must receive the fuel from feed pipes and put it in shape for combustion. With oil this involves atomization, with pulverized fuel, distribution. Secondly, the burner must insure quick, steady ignition. This involves suitable velocities and direction for fuel and air. If part of the controlled air enters a furnace through ports separate from the burner, these ports may be considered part of the burner for the purposes of this article. Finally, the burner must impart this velocity to the fuel and air in such a way that there will be continued turbulence and complete mixing without impingement on furnace walls.

With gaseous fuels distribution is good if the pressure drop through the discharge nozzles is large compared to the velocity head of the gas approaching those nozzles. With natural gas a large number of small nozzles are used in most burners. Nozzle tip velocities at maximum load may be 200 to 1000 ft. per sec. With single nozzle aspirating burners velocities are still higher, requiring up to 10 or 15 lb. pressure. Natural gas burners can be used for coke oven gas, but the proportions must be changed because coke oven gas has only half the heating value, and usually is available only at low pressures. Nozzle velocities with coke oven gas will be 100 to 300 ft. per sec. at maximum load. With blast furnace gas the use of many burners in various parts of the plant make it necessary to figure on low pressures of 1 in. to 5 in. Slow ignition limits nozzle velocities to 60 to 120 ft. per sec. at maximum load.

With blast furnace gas the fuel inlet and nozzles must be designed so that all parts may be thoroughly and easily cleaned at frequent intervals. This involves large doors which must be absolutely gas tight because of the high percentage of poisonous carbon monoxide in the gas. Tight gates must be provided ahead of each burner so cleaning burners will not require shutting down furnaces. Natural gas is always clean, but new lines are not clean, so debris may plug the nozzles. Coke oven gas must always be cleaned before it is piped to burners.

Oil burner manufacturers provide means for quick removal and disassembly of atomizer tubes to permit frequent cleaning. The design of atomizers has become so standardized that it need not be considered here. With mechanical atomizers the discharge orifices are made interchangeable in several sizes to take care of different capacities. The lower capacity limit for an orifice is determined by the lowest pressure at which atomization will take place. For small orifices this is in the neighborhood of 50 lb. for average grades of heated fuel oil. For very large orifices the minimum pressure may be as high as 250 lb. The upper limit of capacity is fixed by the available pump pressure. To keep installation and operating costs of pressure systems within reason the pressures are usually limited to 300 lb., and for small units to 200 lb. If a 2:1 pressure range is available the capacity range will be 30 per cent of full load for any one orifice. Some atomizers have adjustable features which increase operating range effectively, but also increase difficulties with coke deposits in the tips, or increase pumping costs. Good steam atomizing burners have a wider operating range and are effective with lower pressures. Maximum oil and steam pressures vary from 50 to 150 lb.

With pulverized fuel the feed pipes should be connected to the burner with flexible tubing, or with stuffing boxes, if there are adjustments which would be rendered inoperative by distortion of the burner due to the weight of the feed pipe. Pulverized fuel nozzles must have some means of distributing the fuel uniformly in the primary air. In burners having round horizontal nozzles distribution is usually provided by imparting rotation to the stream with involute fuel inlets, deflecting blades, or spiral ribs. None of these devices is perfect and all are very sensitive, so details of design must be painstakingly developed by trial and error.

Distribution is particularly difficult with large burners, because in most cases the length of the nozzle (which determines the time available for distribution) is little if any greater than the nozzle

length in small burners, owing to limitations of floor space. If the difficulty could be measured it would be found to increase at least in proportion to burner diameter, and perhaps in proportion to capacity. Some commercial burners are only about 50 per cent efficient in distributing fuel evenly, and the best are quite faulty with coarse coal. It is, therefore, important that feed pipes be designed to maintain as good distribution as possible up to the burner inlet.

Burners with flat nozzle tips are almost entirely dependent on good feed pipe design for distribution. Baffles within the nozzle or orifice plates at the inlet are of little help. If distribution is good at the burner inlet it can be maintained by proportioning the nozzle with a gradual change in shape and a continuous but slight decrease in area from inlet to tip. Any bends in the nozzle must be exactly at right angles to the long axis of the cross-section.

Pulverized fuel feed pipes can hardly be considered parts of burners, but they are inseparably involved in good burner operation. They should have long radius bends if possible, to minimize erosion, pressure loss, and segregation of fuel. There should be as long a straight run as possible at the burner end.

They should be large enough to offer little resistance to primary air at maximum loads, without being so large that dust will settle out when air is reduced at low loads. A 2:1 variation in primary air may be assumed for a 3 or 4:1 variation in fuel. If the pipe size is selected to give 85 to 95 ft. per sec. velocity at maximum load, the velocity at minimum load will be sufficient to avoid settling out. If a narrow primary air range is expected it is best to figure on 45 to 50 ft. per sec. at minimum load, letting the maximum velocity be some figure below 85 ft. per sec., in order to minimize pressure losses and erosion. With vertical pipes the minimum velocity may safely be 35 to 40 ft. per sec. but with pipes having long horizontal sections minimum velocities should be 55 to 60 ft. per sec. It is not sufficient merely to eliminate deposits which might plug a pipe. Velocities should be high enough to keep the pipes really clean, for the dust which can cling to a pipe having comparatively sluggish air flow is sufficient to cause bothersome pulsations at the burner. Moreover, with feeder systems sluggish air flow permits the fuel to remain in clusters which, with coking fuels, act the same as coarse coal in the furnace.

Burner nozzle velocities are the same as feed pipe velocities except when rotation is used to improve distribution. In this case velocities may be raised as high as 150 ft. per sec. Tip velocities vary widely according to the fuel, the means provided to obtain quick ignition, and the air temperatures used. With whirling burners the velocities can only be approximated because the angle of rotation is not uniform throughout the stream. At maximum loads, tip velocities of primary air with low volatile coals are between 50 and 90 ft. per sec. With high volatile coals they are 80 to 150 ft. per sec. Pressure drops in nozzles at maximum load, to obtain distribution and tip velocities should be 2 in. to 4 in. A drop less than 2 in. is likely to mean poor distribution unless feed pipe distribution is excellent. A drop greater than 4 in. indicates excessive primary air, insufficient capacity, or wastefully designed means of obtaining distribution. In some burners impingement of secondary air on the primary introduces an additional resistance of 1 in. or 2 in.

Ignition of Fuels

After distribution has been provided, the next function is to insure good ignition. A burner can function satisfactorily with imperfect distribution, but it is imperative that ignition occur at all times immediately after fuel enters a furnace, if pulsations and high carbon loss are to be avoided.

In a sense, ignition is a spontaneous phenomenon when a fuel becomes heated sufficiently. Pulverized, liquid or gaseous fuels are heated to ignition temperatures by (1) propagation of flame along the stream of fuel and air, (2) mixture with small currents of hot or burning gases around the burner outlet, (3) radiation from the flame, (4) radiation from the furnace walls, and in some cases (5) impingement with a flaming stream from another burner.

When a fire is started in a cold furnace the sole source of ignition is impingement with a flame from a torch. As soon as proper fuel and air adjustments have been made, propagation along the flame will maintain ignition without the aid of a torch (unless the fuel has a very low combustible volatile content) but in all cases, ignition is somewhat delayed until furnace conditions are sufficiently settled to give a bright flame which can radiate heat back to the burner. Ignition is further aided with modern burners by eddy currents set up within the burner by devices which will be discussed later.

Finally, with early types of burners in refractory furnaces, combustion is best when the furnace has been heated enough to radiate heat back to the burner. This also applies with these burners to a variable extent in water-cooled furnaces depending on the amount of refractory used and the amount of slag adhering to the tubes. It should be mentioned here that the development of burners has had to keep pace with the increasing percentage of water cooling in furnaces. Burners may be designed to provide sufficient means of ignition, for any but the lowest volatile fuels without dependence on radiation from walls.

The most important source of heat for ignition is propagation of flame along the fuel stream, or along eddy currents of that stream. It is perhaps chiefly a radiation phenomenon. At the ignition line, or flame front, the flame of distilled volatile matter is larger, and therefore radiates more heat to the incoming fuel, than those particles of solid fuel which have become incandescent at this point. For this reason propagation is more rapid with high volatile coals and with light oils than with

low volatile coals or heavy oils. It is most rapid with gaseous fuels.

A frequently published set of curves prepared from laboratory experiments in France show propagation rates of 5 to 50 ft. per sec. for various coals with varying amounts of air. A good bituminous coal had a propagation rate of 36 ft. per sec. when mixed with 5 lb. of air and 20 ft. per sec. when mixed with all the air necessary for combustion. A semi-bituminous coal had a rate of only 15 ft. per sec. for the best mixture, and no propagation occurred if more than half the air required for complete combustion was used. The ash content was also shown to be an important factor. This laboratory work did not duplicate furnace conditions, but the results are indicative of what may be expected from propagation along a non-turbulent stream unaided by other sources of ignition. Other experiments have confirmed these results in principle, and have shown that similar variations occur with gaseous or liquid fuels, though not to such a great extent. In order to aid flame propagation heavy oils must be heated, so they will be thin enough to break into microscopic drops, and will be near the distillation point of the lighter fractions, so little heat need be added to start distillation. For the same reason low volatile coals must be pulverized finer, or with more fines, than are needed for high volatile coals.

Major Types of Burners

Early types of burners had very low nozzle velocities, or used a small amount of air with the fuel (see Figs. 1, 2 and 6 in Part I, September, 1931, *Combustion*). Oil was atomized with steam. Pulverized fuel was ground very fine. Even under these conditions flames were smoky when first lit and remained so until the refractory furnace walls were heated sufficiently to radiate heat to the incoming fuel streams.

Good results were obtained, but combustion rates were of necessity low (except in those extreme installations where fuel streams were permitted to impinge on walls) because low velocities did not provide turbulence in the furnace. When it was concluded that maintenance on refractory furnaces was too high, even with low combustion rates, water walls came in. This permitted comparatively small furnaces for the high boiler ratings then coming into vogue so combustion rates went up, and the demands on burners became more exacting.

To obtain high combustion rates efficiently, it is necessary to inject fuel and air at high velocity into the furnace and to effect continued mixing by means of the dissipation of this velocity.

Burners which give simple, streamline jets were found totally unsuited to high velocities. Ignition was delayed and unstable, pulsations were a frequent occurrence. Sometimes they became so severe the fire was extinguished. Flames would "lane" through the furnace and impinge on walls or floor causing erosion and heavy slag deposits. Moreover, direct firing was being applied to large boilers. This called for large burners (some now handle ten times as much fuel as burners used 10 to 12 years ago). Ignition difficulties increase with increasing burner size, because ignition occurs first on the surface of the jet. Difficulties may be said to increase directly with burner diameter, because the perimeter of the ignition line increases as the outlet diameter whereas the total area of fuel to be ignited increases as the square of this diameter. Distribution affects ignition, and, as already mentioned, distribution difficulties increase with burner diameter. These facts are ignored by "old school" men who remember the simplicity of early burners and are scornful of new developments.

Burners designed to give quick ignition with large high velocity streams accomplish this in several ways. First, eddy currents may be created on the surface of the stream by means of baffles or deflectors as illustrated in diagrams a and b, Fig 2. These eddy currents delay the forward progress of part of the fuel, giving it a chance to be ignited by radiation and flame propagation while still close to the burner. These flaming eddies continuously act like torches on the main body of the fuel stream. A second device is to inject the fuel stream into a slower moving body of air while still in the burner, and then discharge the mixture through a hydraulicly inefficient nozzle as in diagram c, Fig. 2. Many steam atomizing burners use this principle in reverse—injecting high velocity steam into slower moving oil—within the atomizer. The scheme is also extensively used in gas burners. Some of these utilize the gas velocity to aspirate just the right amount of air for combustion.

A third development is to produce eddy currents

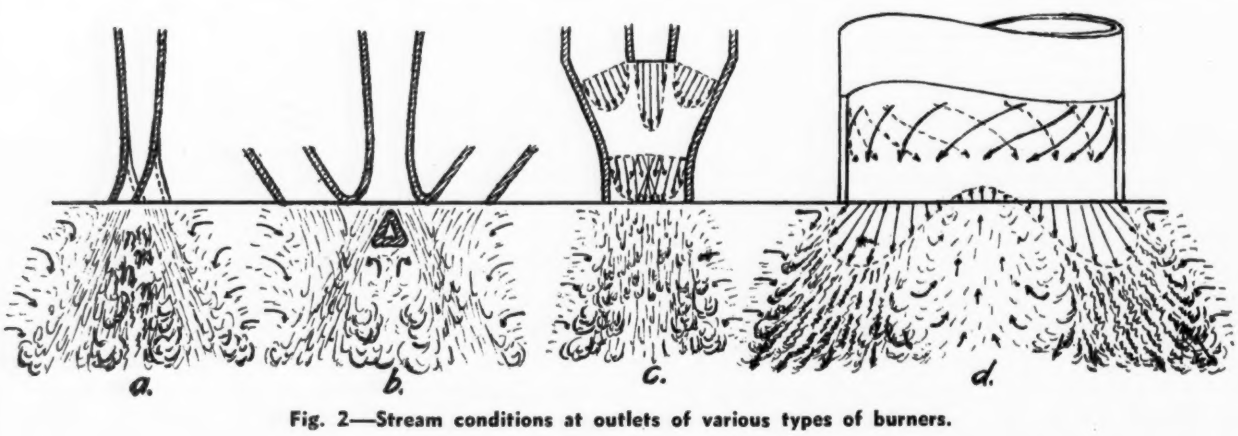

Fig. 2—Stream conditions at outlets of various types of burners.

throughout the fuel and air streams by whirling them rapidly together within the burner as illustrated in diagram d, Fig. 2. In the best designs air enters the mixing chamber tangentially around its periphery. The whirling air admitted farthest from the burner opening is cut into by air admitted along its path. This churning action produces innumerable small eddy currents throughout the mixture. On leaving the burner each element of the stream flies outward tangentially from its circle. This action, plus the forward motion of the entire stream produces a conical flame body. There are great variations in velocity in any section of this conical stream, so the eddy currents continue, even though rotation ceases. The eddies at the outer surface of the cone are slowed down more rapidly by the surrounding gases than the surface of a smooth stream would be, so they reach ignition temperature not far from the burner in spite of their high velocity. Flame is rapidly transmitted throughout the stream by the impact of one eddy upon another.

Conditions at the core of the conical stream vary for different burners or for different adjustments of one burner. If the movement of the average element in the stream along the burner axis is faster within the burner than its rotation about that axis, the conical stream will usually have a solid core, which becomes ignited last. If the reverse is true, the conical stream is hollow, with a core of burning fuel which is being induced back into the burner. In this case ignition will occur first on the inner surface of the cone, and may occur within the burner.

The flame conditions are greatly affected by the relative locations of the fuel and air inlets. Burners with central fuel nozzles are more likely to give hollow flames than burners having annular admission of fuel to the mixing chamber. Greater initial turbulence is caused (for a given air pressure) when air vanes are at or near the burner outlet than when they are behind the fuel nozzle tip or annular fuel chamber. The details of design of the fuel nozzle tip have marked effect on flame conditions, but they are so inseparably involved in the arrangement of other parts of this type of burner that no generalizations can be made.

This type of burner introduces all controlled air with the fuel. As discussed earlier, such a mixture has a much lower rate of flame propagation with any fuel than a mixture which contains only part of the air required for combustion. Moreover, efforts to reduce burner costs (frequently poorly advised) have resulted in larger and larger burners of this type, so improvements in design have barely kept pace with increasing difficulties in obtaining ignition. The intense turbulence within the burner, the large opening exposed to radiation, and the low *average* velocity axially from this opening combine to make the operation of this type of burner quite sensitive. For this reason the more successful designs have several adjustments by means of which the rate of whirling and the point of mixing fuel with air can be altered.

A fourth development was to arrange several burners in a furnace so the flames from each would impinge on the fresh fuel stream issuing from one of the others, as shown in diagram a, Fig. 3. It was found more practical, however, to arrange the

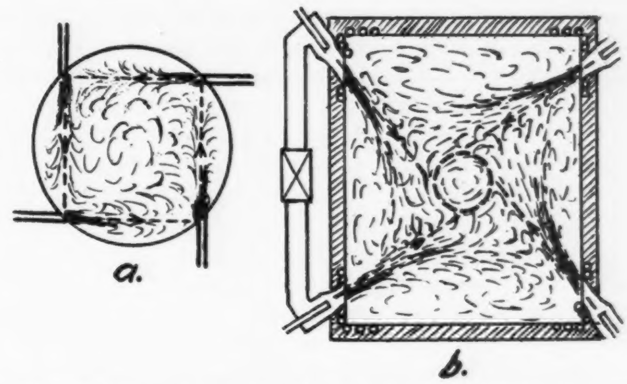

Fig. 3—Stream conditions in tangentially fired furnaces.

burners as in Fig. 5 of Part I, or as in diagram b, Fig. 3, where the burners are pointed at a small imaginary circle in the center of the furnace. The stream from each burner bends the stream from the next burner, so the effect is a much larger "firing circle" than the one at which burners are pointed. Part of each flame tends to travel back along the flame on which it impinges, thus aiding ignition, but this effect in itself is not sufficiently pronounced to give stable ignition because of the high discharge velocities used (100 to 150 ft. per sec.). Moreover, these burners discharge all controlled air with the fuel. For these reasons each burner should be designed as if it were isolated, using the design of diagram c, Fig. 2, to provide eddies within each stream at discharge, and to minimize the blanket of air which otherwise would not mix quickly with the fuel.

Flame Travel

During the discussion on ignition of fuels and on major types of burners the importance of high velocities for high combustion rates was frequently brought out. To avoid damaging the furnace this velocity must be dissipated entirely by interaction between the fuel and air streams or in the case of a single burner, within the single stream itself, without impingement on furnace walls or floor. To avoid high carbon losses the fuel streams must be given as long a path of travel as possible, and the entire furnace volume must be utilized.

With vertical firing this is accomplished by breaking up the momentum of the downward traveling fuel stream by injecting air through front wall ports at right angles to the fuel stream. If the secondary air enters at low velocity, carbon losses are high even though the fuel has a long travel. To avoid early turning of the fuel stream the quantity of primary air has to be increased over that used with low velocity secondary air by adding tertiary air at the burner.

With horizontal firing from round burners in one side of a furnace high velocity is limited to the

region just beyond the burner. After that it is continued somewhat within each eddy current, but these act on each other and the whole stream expands so rapidly in all directions that impingement on walls will not be severe with a well designed and properly adjusted burner. If the furnace is too short or too narrow impingement will occur, especially when a large single burner is used. In such cases the best solution is to use more burners of a smaller size, arranged either side by side, or one above the other, depending on furnace shape. Not all parts of the flame from horizontal burners have equal length of travel, and the front of the furnace is not fully used. These are distinct disadvantages of this type of burner which are overcome only by having an extremely high combustion rate within a comparatively short distance from the burner.

Horizontal firing with flat flame burners was not very successful until recently. No means was provided for rapid dissipation of outlet velocities, so these burners could only be used in small sizes for low combustion rates in comparatively long furnaces. Some burners recently developed, however, create strong eddy currents at the burner outlet which kill high outlet velocities quickly. These are being used with success at high combustion rates.

When furnaces are large enough to justify opposed firing with horizontal burners there is no danger of impingement on the end walls. Because of this the burners need not be designed or adjusted for such bushy flames as are used when firing from a single wall. Burners of the type shown in diagram c, Fig. 2, may be used.

With tangential firing all burners are in one plane, and flames react on each other as described before, regardless of velocities so long as burners are set at a sufficient angle to the walls to prevent flames brushing the walls. They share with vertical burners the advantage of long flame travel.

Relation between Velocities and Combustion Rates

A given combustion rate fixes the velocities required at burner outlets, almost without regard to the type and size of burners. The importance of velocity is seldom realized. Most discussions on rapid combustion refer to "turbulence" and to high burner capacities without indicating how they are obtained.

The factors involved in the selection of a suitable combustion rate for an installation are outside the scope of this article, but Table III gives data from which burner sizes and fan pressures may be determined, for various combustion rates, in usual types of pulverized fuel installations, presupposing commercially complete combustion. At low rates the primary air pressure is usually several inches, and the secondary air pressure a few tenths of an inch. Under these conditions furnace draft can give sufficient velocity to secondary air without the aid of fans.

It will be seen that pressures become impractically high above 30,000 B.t.u. per cu. ft. per hr. The range of velocities and pressures for each combustion rate takes care of variations in fuel, per cent of nominal burner capacity, air temperatures, burner design, etc. A burner which uses up considerable pressure in obtaining turbulence for ignition will as a rule have outlet velocities near the lower end of the range.

TABLE III—VELOCITIES AND PRESSURES FOR PULVERIZED FUEL BURNERS

Combustion rate B.t.u. per cu. ft. per hr.	Outlet Velocity Average of Primary and Secondary Air	Average Burner Resistance and Head Lost to get ignition in. water	Pressure Required at Burner Inlets Average of Primary and Secondary Air in. water
5000	15 to 30	1/8 to 1/4	1/4 to 1/2
10000	25 to 50	1/4 to 1/2	1/2 to 3/4
15000	40 to 70	3/8 to 1	1 to 1 1/2
20000	60 to 90	3/4 to 1 1/2	1 1/2 to 2 1/2
30000	100 to 140	1 1/2 to 3	3 1/2 to 6
40000	150 to 200	2 1/2 to 4	6 to 10

Oil and natural gas burners will function efficiently with velocities 25 per cent lower than these, or in the case of small burners, 50 per cent lower since these fuels mix easily with air. Because of this, natural draft can be used with fair efficiency up to 30,000 B.t.u. per cu. ft. per hr. and combustion rates of 50,000 or more are practical so far as air pressure is concerned. In marine work combustion rates above 100,000 have been obtained with oil, but this is not good practice for stationary plants. The extremely high combustion rates can be obtained efficiently only with the very best designs of burners.

Conclusion

The foregoing discussion has attempted to describe conditions which are common to all burners. Details of particular burners and conditions provided for their operation are being constantly changed so it is not worthwhile to cover them. Each burner can be studied thoroughly if the following points summarized from this article are kept in mind.

1. Feed pipe connections must be large enough for the expected capacity.
2. Means of obtaining good distribution must be provided. This should not introduce an excessive resistance.
3. Air chambers must be large enough to insure good distribution of air.
4. Air vanes or deflectors should be arranged as efficiently as possible to keep secondary air pressure losses at a minimum.
5. There should be adequate means for obtaining quick ignition. This should not require an excessive pressure drop in fuel or air.
6. Means should be provided to remedy possibly too early ignition.
7. Velocities entering the furnace must be consistent with the combustion rates expected.
8. The direction of these velocities must be suited to the furnace shape.
9. Coking fuels should not impinge on heated parts of the burner.
10. All parts of the burner must be shielded from furnace heat, or protected by insulation, or adequately cooled.

11. Adjustments must be substantial enough to be operative in spite of warping of the burner due to heat, or binding of the moving surfaces due to rust, caked coal, blast furnace dust, or oil residue.
12. The burner casing must be substantial enough to take care of expansion strains from feed pipes or air ducts.
13. Nozzles for pulverized fuel must be heavy enough to have long life against erosion.
14. Fuel passages preferably should be free of obstructions where debris can collect.
15. Atomizers for oil should be readily detachable.
16. Parts liable to damage from furnace heat should be readily removable.
17. The interior of the burner casing should be accessible through doors or removable panels. A window through which the interior can be seen is desirable.
18. Nozzles for blast furnace gas should have large gas tight, cleaning doors.
19. It is preferable to have a window through which a fire can be seen at the ignition point and through which a lighting torch can be inserted.
20. In combination pulverized fuel and natural gas burners the coal nozzle should have a tight gate to prevent gas backing up into the coal system when used alone.
21. Large direct fired burners should have provision for blanking off fuel nozzles where there is more than one burner per furnace, so the mill can be worked on with safety.
22. Globe or gate valves should not be used alone on natural gas burners because of possible leakage into the furnace. Plug cocks should be used.
23. Blast furnace gas burners should have tight gates on fuel inlets where there is more than one burner per furnace, so each burner can be cleaned without shutting down the furnace.

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Direct Steaming Effects Fuel Economy and Increases Locomotive Availability

(*Continued from page 19*)

jacks are provided over twenty-five of the fifty house pits to accommodate these locomotives which are held under fire while the necessary work is being done, after which they are moved to outside storage tracks to await departure.

The remaining twenty-five pits in the other section of the house have no smoke jacks and the locomotives occupying this section must be without fire. These locomotives make up the greater part of the second group and the long periods on direct steaming go far to materially reduce the over-all smoke production.

The difference in appearance of the two sections of the house is very striking. With locomotives under fire there is the roar of the blower lines, the emission of smoke and vapor from the stacks and the drafty condition produced by the fans of the unit heaters and the smoke jacks in the roof. A complete absence of noise, smoke and vapor characterizes the other section, and proper temperature is maintained without drafts through radiation from the locomotive boilers, all of which make for an improvement in maintenance work.

Experience at the Boston terminal indicates that, at the prices of locomotive fuel which prevail in New England, a material saving can be made through a reduction in fuel consumption by the proper application of direct steaming.

A large freight locomotive of the Lima type, having a boiler capacity of 47,000 lb. of water, can be held on direct steaming over a complete eight hour enginehouse cycle with a fuel consumption of approximately 100 lb. less per hour than that required to hold the locomotive under fire. This over-all saving can be seriously affected by variations in the condition of the fires at the time when the locomotives reach the ash pit. It is essential that these fires be practically burned out or the loss through the waste of unburned fuel will go far towards nullifying the saving made during the direct steaming interval.

Direct steaming depends on ample power plant capacity which generally means new boilers designed for higher pressures and superheat. The opportunity offered by direct steaming for the production of wide variations in plant load is really remarkable as may be visualized from the possibility of boosting from four to six locomotives each at the rate of from 5,000 to 7,000 lb. of steam per hr. within a thirty minute interval. Control of such a load is absolutely required both in the enginehouse and the plant. A flow meter in the enginehouse provides a picture of the load and an attempt is made to keep the number of boosts at three or less during any one period. In case the load exceeds the capacity of the plant, the main steam valve on the direct steaming line is partially closed.

Three 750 hp. boilers, working at 250 lb. pressure and 150 deg. of superheat make up the steaming units. Turbine-driven unit pulverizers supply the fuel for the furnaces and provide for a ready following of a rapidly changing load.

Steam for coach and building heating and for terminal air compressors make up a part of the plant output which, when properly controlled, is within the capacity of one boiler during the summer months and is readily carried by two boilers during the winter.

Prior to the building of the new enginehouse, locomotives were handled and despatched from three widely separated houses. The new terminal, designed for one hundred departures in twenty-four hours, is now despatching between 130 and 150 locomotives per day without inconvenience or delay—a performance made possible very largely through the increase in locomotive availability which results from direct steaming.

Central Steam Heating Plant Effects Remarkable Economies

By A. M. DODDS
Allegheny County Steam Heating Co.
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The Allegheny County Steam Heating Company, which supplies steam for heating and process work to buildings and industries of Pittsburgh and the surrounding territory, has made a remarkable record of economy in the four years from 1926 to 1930. This economy has been achieved in three directions,—through improvement in metering methods, reduction of leakage and condensation losses in the transmission and distribution system, and by improved steam plant performance. The success of this program is strikingly indicated by the fact that although 1930 sales were considerably above 1929, steam production in 1930 was less than in 1929. The story of this achievement is told and graphically illustrated in the accompanying article.

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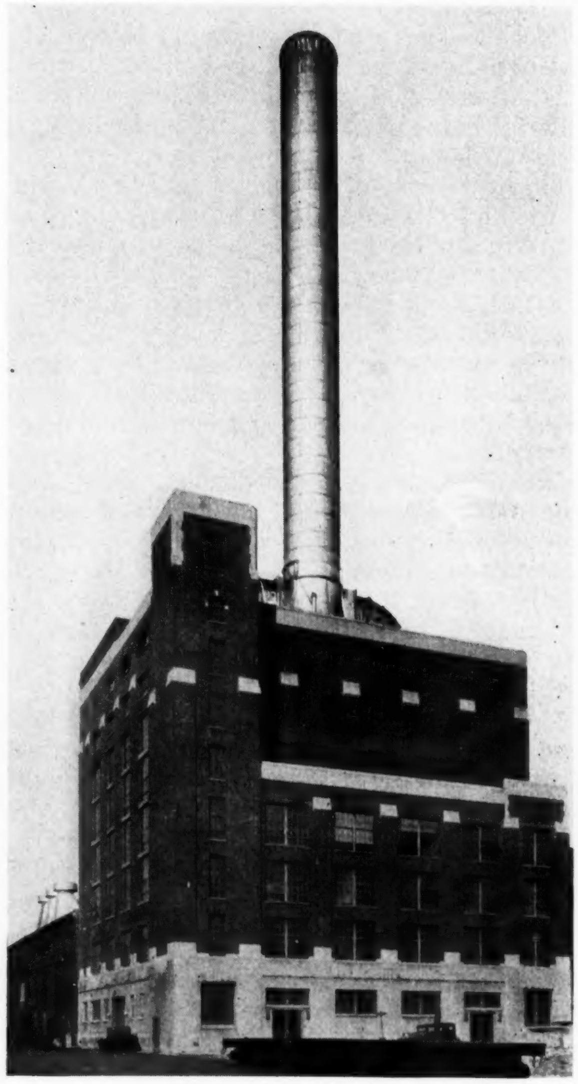

Stanwix Station, Allegheny County Steam Heating Co.

WHILE the total quantity of steam sold by the Allegheny County Steam Heating Company in 1930 was considerably above the 1929 sales, yet the total amount of steam produced at the heating plants was less than in 1929. Believing that the history back of this accomplishment will interest readers, we will explain just what has made this announcement possible.

These results are really the cumulative effect of systematic improvements in the steam heating distribution and production departments over the past several years. Savings comparable to the 1930 economies have been made each year since 1926, each year's savings being added to those of the year preceding, until in 1930 the accumulated total reduction was greater than the growth of steam load. This story is presented graphically in Fig. 1, which shows comparative sales and steam production for the years 1926 to 1930 inclusive.

The lower curve of this chart shows the total quantity of steam sold each year, and the upper, or dotted line, shows the amount of steam which the steam plants would have been required to produce if the percentage of loss between the boilers and the customers had been the same as in 1926. The center line shows the amount of steam actually produced. The area between the dotted upper line and the center line represents steam saved. In the four-year period this area, translated into equivalent coal, means a $70,000 saving in operating expense. This sum is over 9 per cent of the total cost

of coal for the four-year period, and 5 per cent of the total expense of operating all steam heating plants for the same time.

This record of economy has been secured through improvement in three major directions:

1. Improvement in metering methods.
2. Reduction of leakage and condensation losses in the transmission and distribution system.
3. Better performance of steam heating plants and reduction of losses therein.

Improvement in the distribution division has been especially impressive. The combined effect of reduction in losses and of improved metering, has been to effect a 30 per cent reduction in the margin between net output from the steam heating plants and the quantity billed to the customers.

Possibly the most interesting phase, and certainly one of the most important, has been the improvement in the metering of steam service.

As the revenue for the company depends directly upon metering, it is essential that this work be as accurate as possible, so that the company will not operate with avoidable losses. For many years it has been the general practice in most heating companies to meter steam service by measuring the collected condensate, or as much of it as could be collected, and estimating for uses, such as cooking and other process work, where the condensed steam could not be returned to some point for measurement. Even under the best conditions it is a very difficult job to obtain an accurate and complete measurement of the total service supplied, due to leakage and other losses on the customer's premises, in addition to the estimation of some part of the supply. Furthermore, accidental contamination of condensate occasionally occurs and requires quantities to be wasted ahead of the return meter. The net effect of all factors is to the detriment of the heating company, in that the determination of quantity is usually in favor of the customer.

Development of the shunt type of steam meter has presented an opportunity for solution of this problem by measuring all steam as it goes to the customer, thus eliminating many sources of error. This meter has the additional advantage that its integrating mechanism is positive, and the setting can be adjusted so that it will integrate very accurately over its operating range. This type of meter costs considerably more to install than the ordinary condensate meter, but requires slightly less operating attention. Moreover, it produces large returns in more accurate billings for service; and is to the interest of the customer as well by enabling closer study, and consequently, better control of his heating or process requirements.

The Allegheny County Steam Heating Company now has forty-six (46) of these meters in service, the first having been installed in September, 1928. Additional meters of this type will be placed as fast as practicable, the weakest points of the metering system being corrected first.

Systematic Checking

The distribution system operating losses have been reduced by a systematic check and elimination of leaks of all sorts, both steam and water; by improved maintenance methods to reduce heat and condensation loss due to uncovered mains and service lines; by developing an operating schedule for the system so that the steam may be delivered to the customers over the most economical route; by installing apparatus for the detection of contaminated return condensate, and by collecting condensate at connections not previously included; the latter two features reflecting directly into steam heating plant performance.

The systematic check and elimination of leaks as mentioned above includes a periodic physical inspection of the transmission and distribution lines and of the return system, to locate and repair leaking joints and drainage equipment which might be inoperative or functioning improperly, and to guard against unnecessary heat loss through defective or poorly maintained insulation.

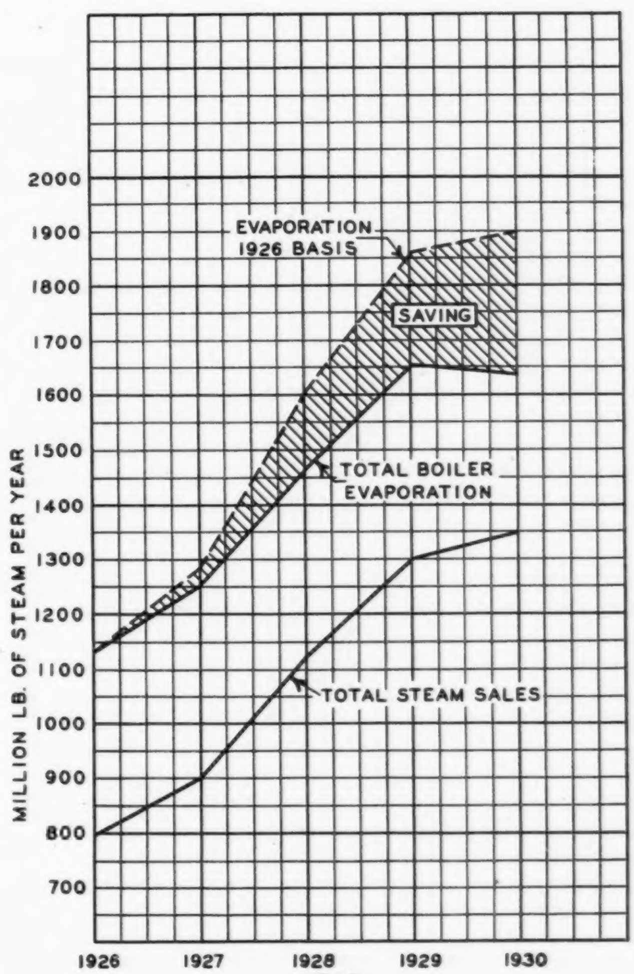

Fig. 1—Improvement in operating performance.

The reduction in losses is shown in Fig. 2. The area between the base line and the first curve represents the usual losses of the transmission and distribution system, being principally heat lost by radiation from a few uninsulated fittings, and normal heat loss from the insulated lines, as it is eco-

nomically inadvisable to provide enough insulation to prevent all radiation loss.

The area marked "Lost on Customers' Premises" is the field in which the principal distribution econ-

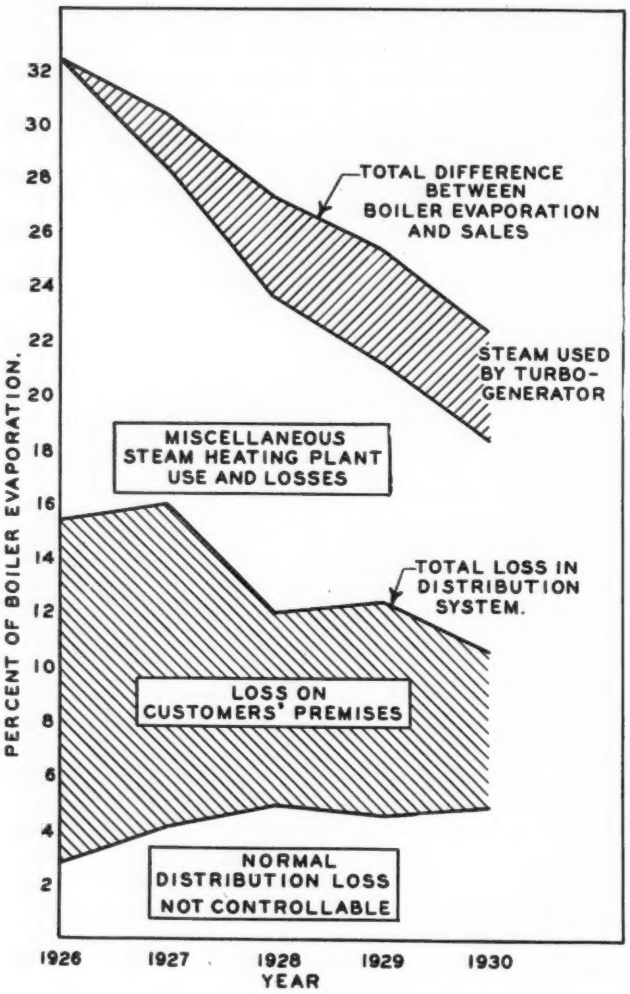

Fig. 2—Reduction of distribution and plant loss.

omies have been made. By improved metering practice and by unceasing work to eliminate poor operating practices on the premises of consumers, this item has been reduced over 50 per cent since 1926.

In addition to the improvement in metering practice already described, which has been the principal method of reducing loss on customers' premises, very appreciable economies have been secured by work in the following lines:

1. Instructing customers in the proper operation of their heating systems:—(a) to insure the condensate reaching the meters, and (b) to prevent the heating system from becoming water-logged in cold weather.
2. Inspections to forestall the loss of condensate from under-ground or under-floor condensate lines which have developed leaks due to rust.
3. The elimination of losses due to faulty heat transfer equipment such as water heaters and economizers.
4. The elimination of miscellaneous steam and condensate leaks on customers' premises.

Improvement in Steam Plant Operation

Miscellaneous use and losses of steam in the heating plants have also been cut approximately in half as shown by the decreasing height of the open area third above the base line.

A further gage of the improvement in steam heating plant operation is the fact that the amount of coal required to produce each thousand pounds of steam has been reduced 7½ per cent in the four-year period.

Some of the moves which have been made in order to effect this improvement were the installation of an improved and more economical type of pulverized coal feeder, partial rebuilding of the pulverizers to improve the fineness of pulverization, improvements to the furnace walls to enable better control of air admission and of flame direction, improvements to the auxiliary power system, improved maintenance methods for boiler interior tube surfaces, and the elimination of leaks and miscellaneous plant losses.

The upper cross-hatched area marked "Steam used by Turbo-Generator" represents the condensation in a 5,000 kw. back pressure turbine installed in 1927 at the Stanwix Steam Heating Plant. This unit receives steam at boiler pressure and exhausts into the low pressure distribution system. In this process some heat is used and the equivalent amount of steam is condensed. The amount of steam available for distribution is therefore that much less than the boiler evaporation. This condition does not enter into the determination of steam plant or distribution system losses, and is shown merely to complete the accounting for total boiler evaporation.

The important feature of this history is that the operating department has had a very definite problem, that of reducing excessive losses to a reasonable quantity, and has already made great progress by consistently following a common sense program of corrective measures. Much of the credit for this work belongs to Mr. W. W. Stevenson, Steam Heating Engineer, who has been principally responsible for the changes and improvements in the distribution system.

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Correction

In the article, "Marine Steam Generation," by David Brownlie which appeared in the September, 1931 issue of COMBUSTION, it was stated in the second paragraph on page 42 that the condenser tubes "are made of special 'A.E.' super-nickel non-corrodible steel supplied by Allen Everitt & Sons, Ltd." Since the publication of this article we have been advised that these tubes are made of 70/30 copper-nickel.

Some Advantages of the Proper Selection and Inspection of Coal

By F. B. DOANE
Pittsburgh Testing Laboratory,
Pittsburgh

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Coal represents from two-thirds to three-quarters of the total cost of power; hence, the importance of selecting that coal for a given plant that represents the best value both from the standpoint of performance and economy. The author emphasizes the fact that the cheapest coal available is not necessarily the most economical fuel, even though it may have a high heating value. The factors of ash content, ash fusion temperature and moisture must also be properly evaluated in conjunction with consideration of the limitations imposed by firing equipment, operating conditions, etc. Careful and accurate sampling is also essential if the results of analyses are to be relied upon.

TO the buyer of coal, heat values, fusion points, freight rates and delivered and mine costs present a complicated maze which appears difficult of solution. The complexity of the problem is further borne out by closer study and examination. Those in the past who have had the patience and time to carefully study and tabulate coals on the basis of the above classifications have repeatedly shown that the delivered cost of a given coal is no indication of its value. Putting it another way, in any given price range, coals may be had covering practically the extreme range of value.

Carefully scrutinized production costs characterize the present period, and the cost of every raw material entering into the manufacture of a product is closely watched. Power is not the least important of these materials, and coal represents from two-thirds to three-quarters of the total cost of power. As the foregoing paragraph indicates, cheap coal does not necessarily mean cheap power. The reduction of power costs to the minimum rather involves the use of that coal which, with a given plant, will yield the cheapest steam, for low cost of steam is the paramount factor in low cost production of power.

How shall coal be selected? Can its performance be indicated in advance? Fortunately there is a well-grounded feeling in the mind of the modern buyer that it can be—a growing reluctance to make a trial of this and that coal, and an inclination to get away from trial and error methods of selection. Offsetting this is a tendency to accept the cheapest coal and strive by increased efforts and attention to improve the operating efficiency.

The true course does not lie in either of these paths alone, but in both, for each tells only half of the story and neglect of either is fatal to economical steam generation.

Selection of Coal

Now, if the buyer can select in advance the most economical coal, which, as has been pointed out, is probably not the lowest in unit cost, and if he can make sure he is getting the specified qualities in the coal as delivered, then half his problem is solved.

One of the odd things about coal is that not the coal itself but the impurities it contains decide in advance what its performance will be. By far not the most important criterion of a coal is its heat value, and buying coal on a B.t.u. basis may be a costly mistake. Much more important is the behavior of the fused bed on the grate bars and the degree of its tendency to clinker. Naturally a coal which produces serious clinker trouble is rejected, after the trouble has occurred, but what of the coal which still causes some trouble—not enough to cause instant rejection, but only serious difficulty? Frequently it continues to be used by virtue of extra effort on the part of the firemen, but only at the cost of lowered efficiency.

Fortunately, the clinkering tendencies of coal are well indicated by the fusion temperature of the ash, as determined in the laboratory. In addition to fusing point, the moisture content must be considered, because it will vary the heat value per pound of coal as burned and consequently the evaporation per pound.

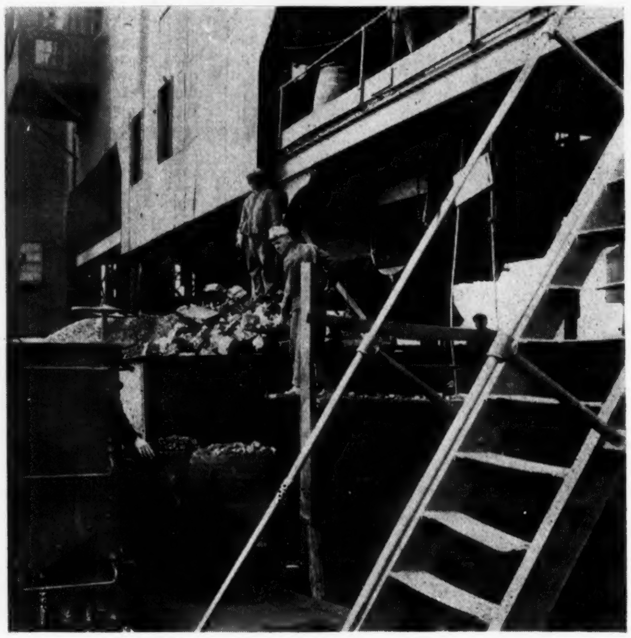
Ash, fusion point, moisture and heat value as determined by the laboratory are true indications of the performance to be expected from a coal with a given plant, and firemen and laboratory supplementing each other should be able to rule out nearly all the guess work in coal selection. In other words, where several coals are available for purchase, and all are apparently suitable in a given plant, a consideration of these factors (ash, fusion point, moisture, heat value), together with the delivered cost, may be relied upon as a proper guide to the selection of that coal which represents the best value from the standpoint of both performance and economy.

With the existing equipment and an average set of ratings, known to the engineer in charge, it is possible for him to maintain the expected degree of performance, *provided* his fuel runs fairly uniform. Supposing, however, the buyer is offered a new coal at what seems like a much lower price per unit. Is he to accept it and pass it on to the fireman to use as best he may, meanwhile congratulating himself on his buying acumen? The chances are that he is safe, if he sees an analysis, properly interpreted, showing the fusion point to be as high or higher than the coal he has been using. His plant trials, of course, must be intelligently interpreted.

Inspection of Coal

Having satisfied himself that the analyses, either as furnished by the seller or as determined by the buyer's own laboratory or a commercial laboratory, on samples submitted by the seller, is satisfactory, the next step is to make sure by proper inspection that the coal as delivered falls within the desired specification range.

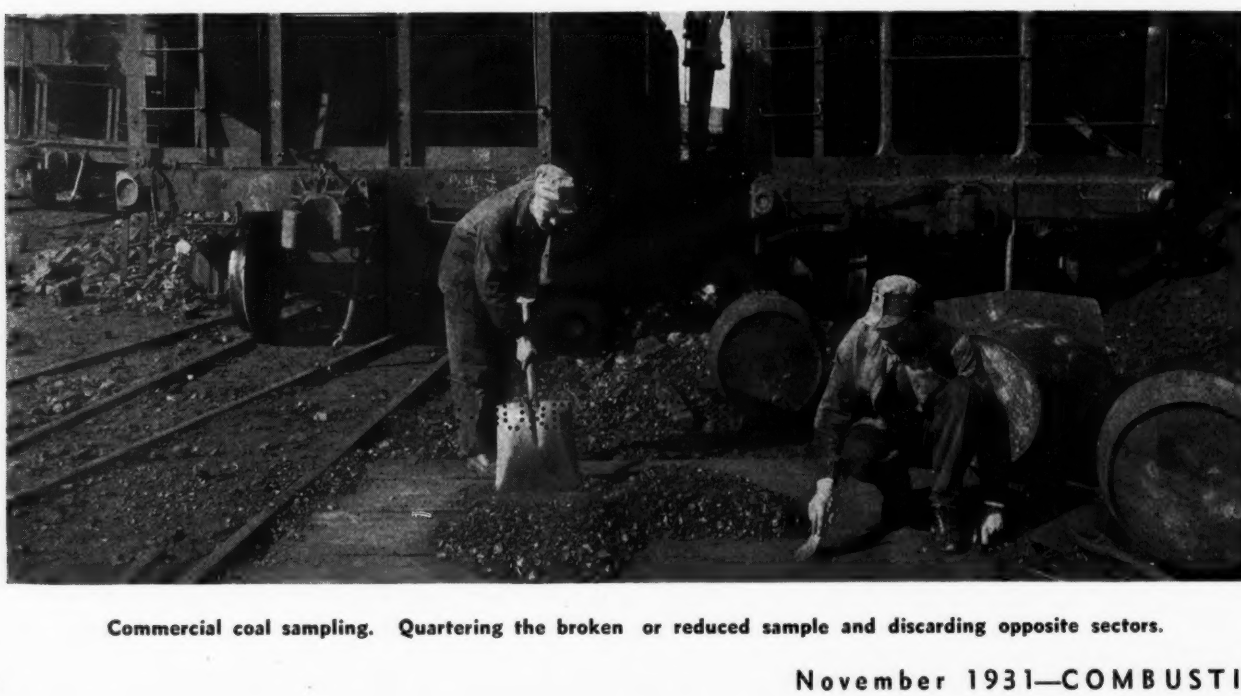
Careful, correct sampling, either at the mine before shipment is made or on the cargo or car as received, is necessary; otherwise all the time and trouble expended in careful analysis and selection is wasted. This work should be done by conscientious, experienced samplers. Variations of 5 per cent, and considerably more in some cases, commonly occur, and, if the work of sampling is not properly done, a large number of samples must be taken and analyses made to arrive at the true average.



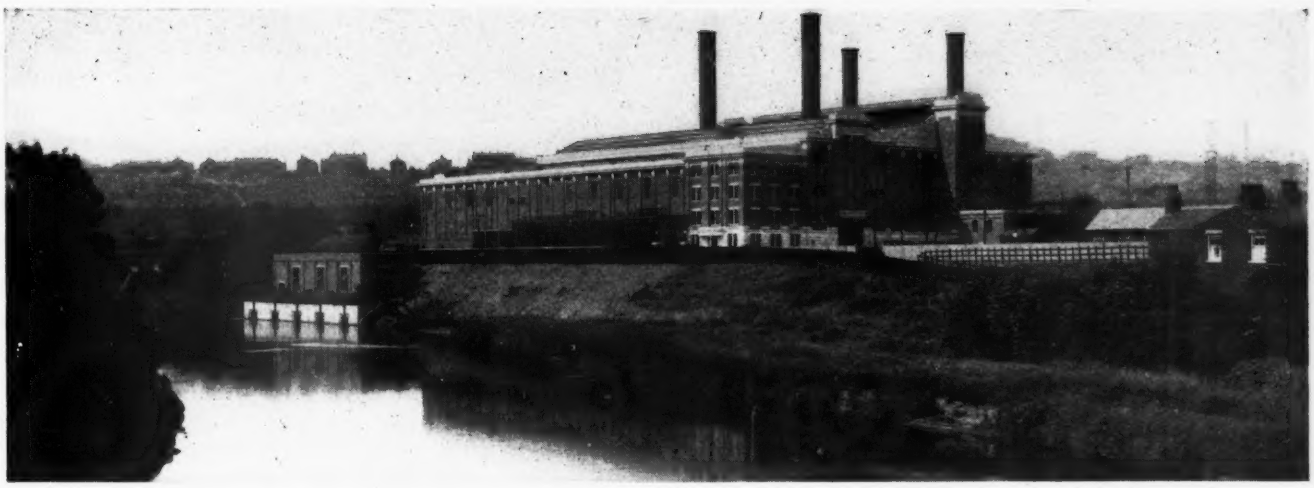
Sampler securing coal as it is being loaded into car and stored in barrels preparatory to crushing. 1000 lb. of coal are taken as a gross sample.

Selling Coal on Quality

To the progressive seller of coal, users' needs offer an opportunity to lift his product out of the field of price competition. Scientific coal selling, based on actual worth to the user, is not a hindrance but a real help to the producer who is able and willing to offer the best values.



Commercial coal sampling. Quartering the broken or reduced sample and discarding opposite sectors.



Kearsley Station, Lancashire Electric Power Company, Stoneclough, England

The Most Efficient Power Station in Great Britain

The Kearsley Station of the Lancashire Electric Company is the most efficient power station in Great Britain, heading the list for 1930 with a thermal efficiency of 23.84 per cent. Operating at moderate steam temperature and pressure and along highly conventional lines in every respect, the record of this station has served to give some substance to those who favor the type of practice it represents. The designers and operators of the modern super station will, however, find much to disagree with in the economic theories of those responsible for the design of Kearsley which theories are subscribed to by the author of this article. Such disagreement will apply not so much to the application of these theories to the conditions existing at Kearsley as it will to their general value and utility.

By DAVID BROWNLIE,
LONDON

UNDOUBTEDLY one of the most remarkable power plants in the world is Kearsley, at Stoneclough, near Manchester, belonging to the Lancashire Electric Power Company.

The recently issued Annual Report of the Electricity Commissioners (British Government) for the year ending December 31, 1930, shows that Kearsley heads the list for thermal efficiency of about 330 public supply power stations in Great Britain. The station is remarkable not because of large size, super steam pressures, very high superheated steam temperatures, and other modern methods of securing the utmost in terms of overall efficiency, but rather because of the absence of these features, generally regarded as essential to the best results.

Thus the total capacity is only 64,000 kw., with a yearly output of about 130,000,000 kw-hr., steam pressure, 315 lb. per sq. in., and average superheated steam temperature, 685 deg. fahr. along with moderate air heating, about 200 to 250 deg. fahr. in the air as delivered, and 200 deg. fahr. in the feedwater entering the economizer. There is no provision for dust separation because it is claimed no dust nuisance is caused, and there are no evaporators and no deaerators. Further, only relatively simple instruments are in use, such as CO_2 recorders, pyrometers and draft gages, with no automatic control equipment. As regards the duty, this is much below the normal, being 6.65 lb. evaporated per sq. ft. of boiler heating surface per hour.

The twelve leading power stations in Great Britain for the year 1930 as regards thermal efficiency are given by the Electricity Commissioners as follows:

Name of Power Station	Kw.-hr. generated, millions	Coal per kw.-hr., pounds	Thermal efficiency, per cent	Annual load factor, per cent
Kearsley (Manchester)	129.6	1.17	23.84	42.3
Deptford West (London)...	280.8	1.29	23.20	43.3
Barking (London)	543.3	1.38	23.02	37.2
North Tees (Newcastle)....	255.1	1.26	22.69	50.2
Hams Hall (Birmingham)...	133.6	1.46	22.50	34.6
Barton (Manchester)	402.9	1.31	22.23	41.7
Ferry Bridge (Yorkshire)...	158.5	1.31	22.23	45.2
Spondon (Derbyshire)	126.2	1.51	21.93	46.5
Bonnybridge (Scotland)	50.2	1.48	21.48	52.5
Portishead (Bristol)	106.9	1.35	20.56	30.5
Lister Drive No. 3 (Liverpool)	267.5	1.47	20.36	56.7
Deptford East (London)....	249.3	1.53	19.96	30.0

It is seen that Kearsley is exceeded in size by eight of these stations, of which Barking (London) has nearly five times the output while Barton, (Manchester) is nearly four times as large. Also the load factor of Kearsley is not abnormal being 42.3 per cent, and six of the twelve stations are better situated in this respect.

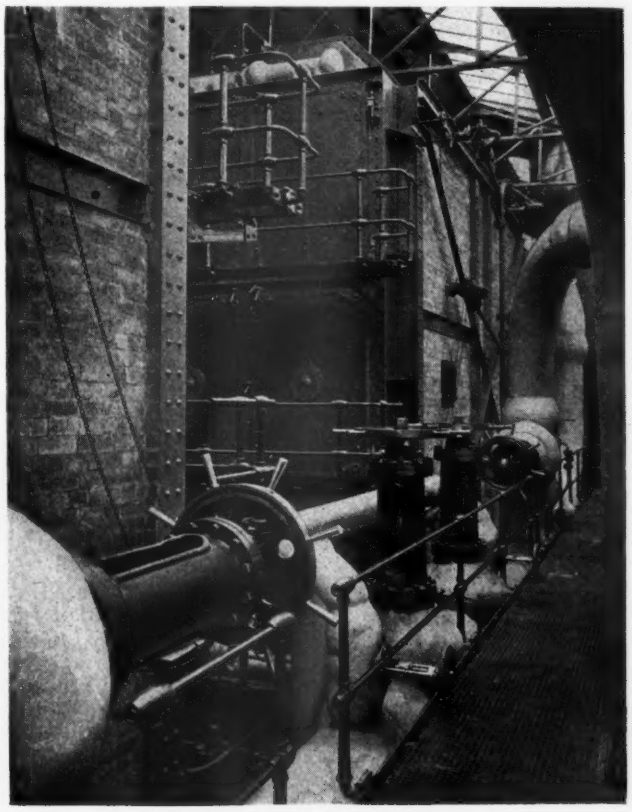
Naturally one asks therefore what is the explanation of the results, especially as these figures of 23.84 per cent thermal efficiency represent the actual performance for the whole of the year 1930, with a consumption of 67,907 tons of coal and a sale of 123,478,306 kw.-hr. Even in these days of super-pressures of 600 to 1800 lb. per sq. in., 800 to 900 deg. fahr. superheated steam temperatures, gigantic boilers of 400,000 to 1,000,000 lb. evaporation per hr. and plants of 500,000 to 900,000 kw. there are not many of the world's modern stations running at over 23¾ per cent thermal efficiency with less than 42½ per cent load factor.

In fact according to many generally accepted ideas upon power station practice a small plant of 64,000 kw., with boilers of only 75,000 lb. normal evaporation working at 315 lb. steam pressure and 685 deg. fahr. temperature, certainly could not be expected to operate at 23.84 per cent thermal efficiency.

The explanation, expressed in a few words, seems to be steam generation under extremely easy conditions without any attempt to obtain high duty boiler performance, combined with operating skill and an unusual degree of enthusiasm on the part of the engineering staff. The whole station is designed on simple and practical lines with no steam whatever used for any other operation than driving the two main 32,000 kw. turbines. All the auxiliaries, without exception, including of course feed and circulating pumps, as well as air pumps, are driven by electric motors so as to keep an accurate continuous record of the performance and avoid minor wastage of steam. The main point as regards operation is the easy working of the stoker-fired boiler units, the contention being the general principle of operating at very high ratings is bad policy, resulting in troubles with wear and tear, maintenance, excess air, dust and grit, and unburnt material.

Interior view of Kearsley plant showing stokers, boilers and coal feeding arrangement.

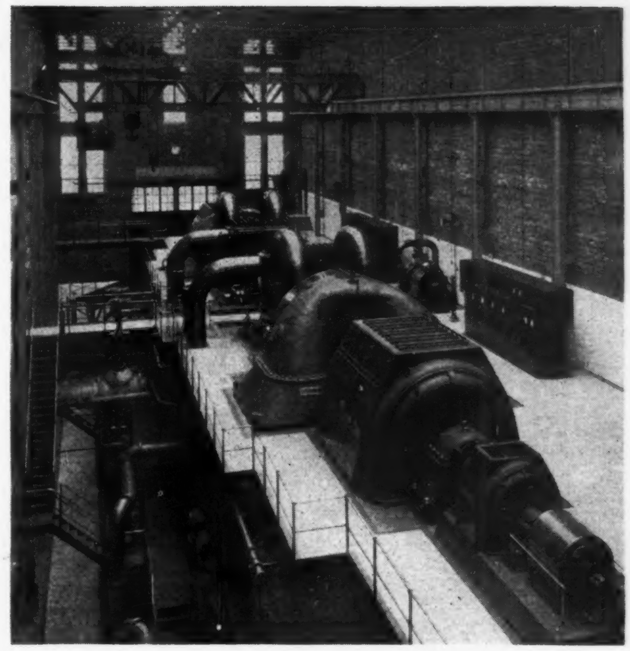
The boiler plant consists of 8 B. & W. cross drum marine type boilers, each of 11,675 sq. ft. heating surface, with superheaters of 5588 sq. ft. heating surface and tubular air heater of 11,713 sq. ft. heating surface, and green cast iron economizer of 8,496 sq. ft. heating surface, with operating conditions, as stated, of 315 lb. pressure and 685 deg. fahr. superheated steam temperature with 710 deg. fahr. maximum. The boilers have a normal evaporation of 75,000 lb. per hr., and are fired by chain grate stokers of 396.0 sq. ft. grate area each, with air and draft requirements met by forced and induced draft fans. Each pair of boilers has one chimney 112 ft. high. The reason why no trouble results from dust and grit omission even with such short chimneys, is claimed to be because of the low velocity of the combustion gases, combined with a downward flow through the



Boiler operating gallery.

economizers and air heaters before entering the chimneys.

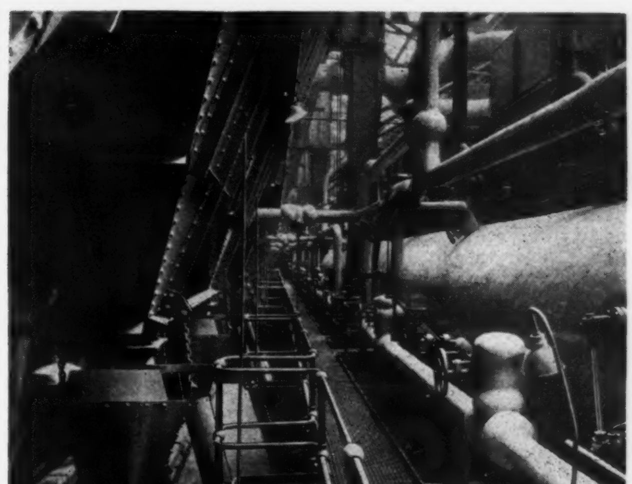
The two 32,000 kw. turbo-generators are of British-Thomson-Houston make, and run at 1,500 r.p.m. with 29 in. of vacuum, the air ejectors being operated by water. The most economical rating is 25,000 kw. For each turbine, there is a 750 kw. house generator and an exciter driven from the end shaft of the main turbines. All the auxiliaries are electrically driven. For feedwater heating low pressure steam is taken only from the turbines, operated on the 2-stage principle, and for this reason a large installation of both economizers and air heaters is included, the average temperature of the chimney gases being only about 220 deg. fahr. The make-up water is softened in a Kennicott dual



Turbine room at Kearsley.

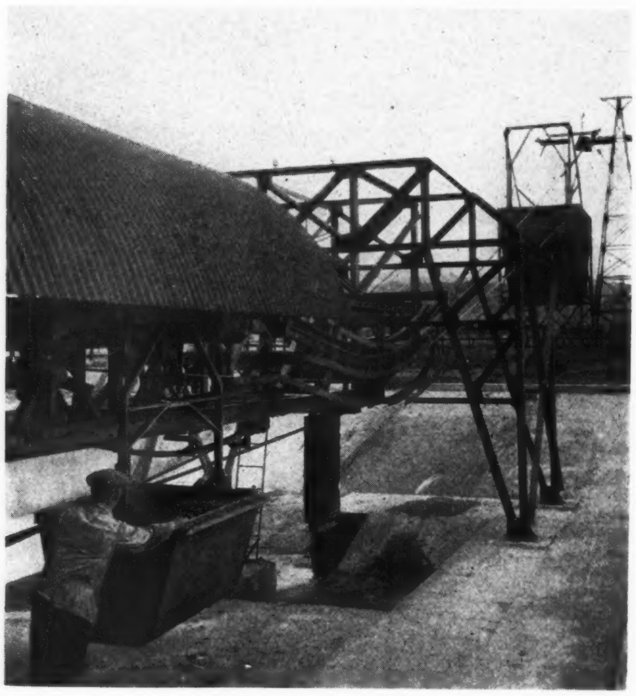
lime and soda ash and Base Exchange softener, with deaeration by admission to the condensers, while the boilers are emptied after every 800 hours steaming. The coal is brought by rail, the cars being handled in the sidings by electric locomotives. The installation includes a wagon tippler house with passage over weighing machines before and after, the coal being delivered either to the boiler house bunkers or to the storage dump by drag scraper conveyors. Ash is removed on a runway in the boiler basement under all the ashpits, using steel skips into which the ashes are dumped; the loaded skips being then taken round to the end of the basement and quenched. All the ash can be sold locally for road making.

The Kearsley station is coupled up by 33,000 volt cables to two other smaller stations belonging



Gallery at boiler drum level.

to the Lancashire Electric Power Company, that is Radcliffe and Padiham, the latter being 20 miles north. In addition the circuit joins up to the Barton power station, of the Manchester Corporation which is 12 miles south, also on the River Irwell. The average continuous all the year round performance of Kearsley is 23.8 per cent thermal efficiency from the raw coal to the switchboard, 83.8 per cent steam generation efficiency gross or 82.2 per cent after deducting all auxiliary power, an evaporation of 6.65 lb. of water per sq. ft. of heating surface per hr. and a maximum of 23.5 lb. of coal burnt per sq. ft. of grate area per hour.



Ash skip at terminal of runway.

A detailed short test of one of the boilers, running under actual normal operating conditions with considerable fluctuations in the steam demand, gives the following figures for a 6-hour test:—

(1) Coal burnt	47,488 lb.
(2) Coal burnt per boiler per hr.	7,915 lb.
(3) Quality of coal used:	
Ash	7.30 per cent
Moisture	11.92 per cent
Heating value as fired	12,070 B.t.u. per lb.
(4) Total water evaporated	415,098 lb.
(5) Water evaporated per boiler per hr.	69,183 lb.
(6) Temperature of feedwater to economizer	200.8 deg. fahr.
(7) Temperature of feedwater from economizer	280.0 deg. fahr.
(8) Steam pressure at superheater outlet	301.4 lb.
(9) Superheated steam temperature	714 deg. fahr.
(10) Temp. of flue gases, boiler outlet	516.2 deg. fahr.
(11) Temp. of flue gases, economizer outlet	320.6 deg. fahr.
(12) Temp. of flue gases, air heater outlet	234.9 deg. fahr.
(13) CO_2 in dry gases, by volume	11.3 per cent
(14) CO in dry gases, by volume	0.0 per cent
(15) Oxygen in dry gases, by volume	8.1 per cent
(16) Coal burnt per sq. ft. grate area per hour	19.98 lb.
(17) Air used per lb. of fuel	14.46 lb.
(18) Water evaporated per lb. coal as fired	8.74 lb.
(19) Gross overall efficiency	87.68 per cent

The main figures for the detailed operating results at Kearsley for the whole of the year ending December 31, 1930, are as follows:—

(1) Total units generated	129,624,646
(2) Total units delivered to feeders	123,478,306
(3) Total units used in the power station	6,136,340
(4) Percentage total power output used in station	4.74
(5) Maximum load on feeders	35,000 kw.
(6) Load factor	40.27 per cent
(7) Total coal burned	67,907 tons
(8) Proximate analysis of coal as fired (dry basis):	
Fixed carbon	58.29 per cent
Volatile matter	33.34 per cent
Ash	8.37 per cent
Moisture	0.00 per cent
Heating value	12,200 B.t.u.
(9) Coal used per unit generated	1,173 lb.
(10) Amount of ash to dump	8.79 per cent
(11) Combustible matter in ash	5.59 per cent
(12) Average vacuum at turbine exhaust	29.16 in. mercury
(13) Maximum river temperature	75.5 deg. fahr.
(14) Minimum river temperature	38.0 deg. fahr.
(15) Temp. of air entering air heater	70 deg. fahr.
(16) Temp. of air leaving air heater	234 deg. fahr.
(17) Steam pressure at boiler drum	316 lb. per sq. in.
(18) Steam pressure at turbine stop valve	301 lb. per sq. in.
(19) Superheated steam temperature at boiler stop valve	696 deg. fahr.
(20) Superheated steam temperature at turbine stop valve	684 deg. fahr.
(21) Total water evaporated	1,294,960,200 lb.
(22) Water evaporated per lb. of coal	8.513 lb.
(23) Water evaporated per lb. of coal from and at 212 deg. fahr.	10.59 lb.
(24) Temp. of feedwater to economizer	195 deg. fahr.
(25) Boiler house efficiency	83.82 per cent
(26) B.t.u. per kw. to feeders	15,030
(27) B.t.u. per kw. generated	14,310
(28) Overall thermal efficiency, units generated	23.84 per cent
(29) Overall thermal efficiency, units to feeders	22.7 per cent

This corresponds to a coal consumption of 1.173 lb. per unit generated on the year's sum while the coal averages $3.60 per ton, (2240 lb.) delivered.

It may be stated that the first small power station of the Lancashire Electric Power Company, erected at Radcliffe in 1905, always had a high record for efficiency, while the second station of the Company started up at Padiham in 1927, immediately occupied the following year the first place in the whole of Great Britain although also only a small station with an annual output of only 67,000,000 kw.-hr., being the 47th station in size in Great Britain. The load factor is fairly good being 42.5 per cent, but the steam pressure is only 200 lb. per sq. in. and the superheated steam temperature 620 deg. fahr. In spite of this Padiham, having also small chain grate stokers with no air heaters and no bleeder steam for feed heating, operated in 1928 with 1.33 lb. coal per kw.-hr. and 21.35 per cent thermal efficiency. Then it lost the lead in 1929 but now in 1930 Kearsley has taken the premier place with 1.17 lb. coal per kw.-hr. and 23.84 per cent thermal efficiency.

In considering these results at Kearsley in the first place I should like to state they give me particular pleasure because for years past I have pointed out that mere size and cost of a power station does not necessarily mean the highest efficiency. Here in Great Britain the Electricity Com-

(Continued on page 44)

Liability of Heating Company for Negligence in Making Steam Supply Connection to Building

By LESLIE CHILDS
Indianapolis, Indiana

According to this judgment, a steam heating company is liable for damages occurring within a building as a result of a faulty connection made by the heating company when such connection is made within the building supplied. Apparently, a judgment can be obtained irrespective of whether the damage is done to property of the building owner or to the property of tenants even though the steam heating company has no contractual relationship with the latter.

GENERALLY speaking, where a commercial heating company merely delivers steam to a building at the curb, it will not be liable for damage caused by escaping steam within the building, as a result of defective equipment therein. This assuming that the company is not the owner of the inside equipment and is under no legal duty to exercise supervision thereover.

However, where such a company connects with a building from the inside, we have a somewhat different situation, and here, if damage results from negligence in making the connection, liability may attach to the company therefore. The application of this rule of liability is illustrated in a striking manner in a recent case that arose under the following state of facts.

Here the defendant, a heating company, contracted with the tenant of a hotel building to furnish steam for the whole building, including the subtenants. When this contract was entered into, the private steam heating plant of the building was abandoned, and the defendant made a connection by running a pipe into the building from its main in an alley thereby.

In making this connection, the defendant first ran a four-inch pipe from its steam main in the alley to the concrete wall of the building. It then cut a groove in the outer face of the wall about six feet up to a boarded window at which point a four-inch angle valve was attached, which was largely in the wall. The valve was then reduced from four inches to two and one-half inches by a cast iron bushing. A pipe of this size was then screwed into the bushing and extended to the furnace room where it was connected with the pipes of the building for distributing steam.

Through some apparent oversight, the pipe that was screwed into the bushing only entered about one-quarter of an inch. However, this arrangement worked about two years when the threads in the pipe gave way, and filled the furnace room with escaping steam. Before this was discovered, the steam billowed upward, filled and penetrated the store room of the plaintiff above, who was a subtenant, and damaged his stock of merchandise in the sum of $1,602.00.

Plaintiff then brought the instant action against the heating company for his loss. The latter defended on the ground that it was not liable to plaintiff because it had no contract with him. The trial court held the evidence showed negligence on the part of the heating company in making the connection, and held it liable in tort for the loss. From this judgment the heating company appealed, and the higher court in affirming the judgment, in part, said:

"We are unable to see that the heating company can be absolved from liability * * * under the circumstances attending its making the installation, here appearing. It seems to us that the trial court was warranted in regarding the heating company's installing of the valve and attachments, which included the cast-iron bushing and the screwing of the two and one-half inch pipe therein, as being made by the heating company for itself to the end that it might thereby deliver to the hotel tenant with which it then dealt steam for the building. * * *

"We think the heating company was not only charged with the proper and safe installing of the valve and appliances in question, but was also charged with the duty of continuing inspection and care of the valve and its immediate attachments incident to its continuing to deliver steam into the pipes in the building, and for failure in such duty the heating company became liable for damages resulting therefrom to any of the tenants of the building.

"True, the heating company's contract was not with any tenant of the building other than the hotel company; but we think the heating company's liability to an injured tenant of the building, from escaping steam resulting from improper installing and maintenance of the valve and attachments here in question, would be a tort liability, and therefore not dependent upon a contractual relation between the heating company and such injured tenant."

Then, as to the negligence of the heating company in making the connection, the court continued:

(*Continued on page 41*)

Diphenyloxide for Preheating Air*

By JOHN J. GREBE
Director, Physical Research
Dow Chemical Company, Midland, Mich.

Use of diphenyloxide for preheating air at the Bremo Station of the Virginia Public Service Company marks the first large-scale operation of a power plant employing a high-boiling-point organic compound. The field of high-boiling, organic, heat-transfer agents has been so enticing that many proposals have been made and a considerable amount of experimental work has been done to determine their applicability. Mr. Grebe describes the application at Bremo, briefly summarizes the use of such compounds as heat-transfer agents, and describes the nature and type of apparatus required.

THE fundamental reason for considering the use of diphenyloxide, diphenyl, and mixtures of these with naphthalene for heat-transfer purposes is that they permit operation at high temperatures with moderate pressure and that these particular compounds are more stable than others in their boiling range. The thermal and the heat-transfer properties of these compounds are so nearly the same that experience gained on one material can be applied to the others. The Bremo Station uses a mixture of 85 per cent diphenyloxide and 15 per cent naphthalene in order to obtain a eutectic melting at 65 deg. fahr. The eutectic of 74 per cent diphenyloxide and 26 per cent diphenyl melts at 56 deg. fahr. The pure materials have the following properties:

	Melting point, deg. fahr.	Boiling point, deg. fahr.
Diphenyloxide	81	496
Diphenyl	165	495
Naphthalene	176	424

These compounds are non-corrosive and non-poisonous, so that the equipment required for their use consists of standard steel construction. Except in special cases, there is no advantage in using diphenyloxide where the maximum temperature required is less than 500 deg. fahr.

Above the temperature of 750 deg. fahr., diphenyloxide slowly decomposes to other organic compounds, and then one is faced with the problem of balancing the cost of purification and replacement of the material against the advantages derived. As all know, even water decomposes to form hydrogen and iron oxide unless the necessary precautions are taken.

For very high temperature ranges there is no better heat-transfer medium than mercury, which, being an element, cannot be decomposed. The adaptation of the Brown Boveri boiler or the Loeffler boiler system to the problem of boiling mercury may solve what at present is the most difficult feature in connection with the use of mercury.

It can be seen from the foregoing that any material, be it liquid air, carbon dioxide, ammonia, water, diphenyloxide, or mercury, has its own specific range of temperature within which it is most useful for heat-transfer purposes. The list of suitable heat-transfer fluids could be increased very considerably.

No Advantage in Superheated Vapor

Heat is transferred preferably by the use of heat of vaporization wherever constant temperatures are required. Where materials are to be heated without evaporation, the sensible heat or the superheat in the heat-transfer materials is generally used in order to permit the use of a counterflow system. In the case of diphenyloxide, there is no advantage in superheated vapor, since the pressure required for saturated vapor at 750 deg. fahr. is only 135 lb. gage. At the Bremo Station (1, 2)[1] the sensible heat of diphenyloxide is used, since it requires simply that the liquid be circulated through economizer tubes for heating and through air-preheating tubes for removing heat from the diphenyloxide. Essentially, the system is a closed heat-circulating system using diphenyloxide liquid to carry heat taken from the flue gases to the combustion air. Since the boiler is of the single-pass vertical type, a conventional air-preheater design would have entailed an increase in building height and expensive duct work. This was avoided by installing a relatively small economizer on top of the boiler, carrying the heat absorbed down to the burner floor in diphenyloxide and releasing it in air heaters placed at the point where the air enters the boiler.

In addition to these advantages, which are peculiar to the Bremo Station, other savings were incorporated in the design and still others were dis-

* Presented at the Kansas City Meeting, Sept. 7 to 9, 1931, of The American Society of Mechanical Engineers.

[1] Numbers in parentheses apply to the references at end of article.

covered during the period of preliminary operation. The construction of the system presented little in the way of difficulties, actually causing less trouble than the erection of a standard air heater with duct work. The operation of this new type of air preheater was so facile and trouble-free as to require practically no attention. Boiler-room appearance is greatly improved by the air-heater system, presenting the illusion of being an integral part of the boiler. Another feature is the individual control

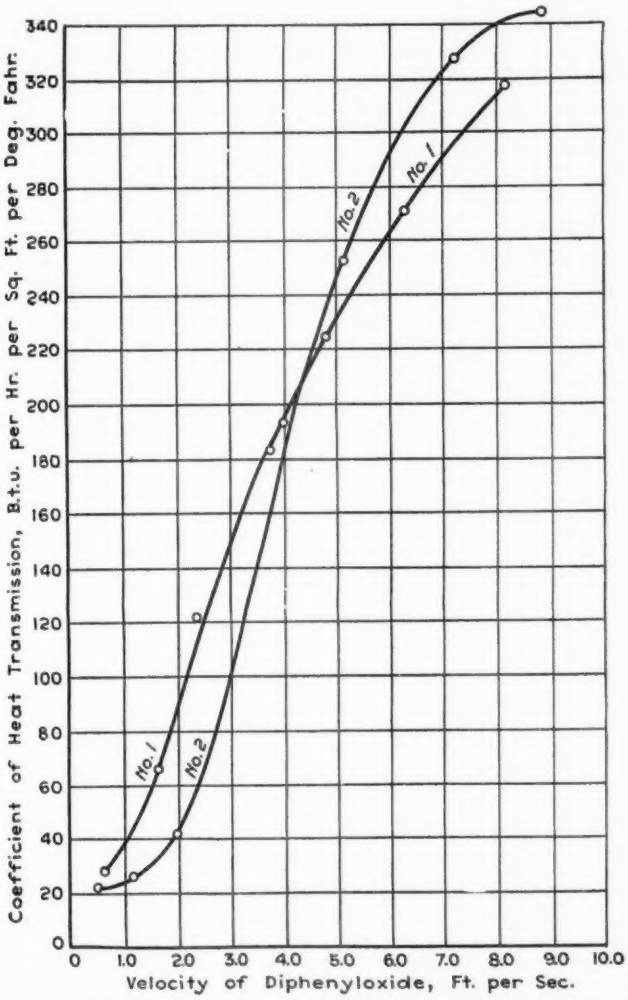


Fig. 1—Overall coefficient of heat transmission between liquid diphenyloxide and steam (condensing).

(Separating wall: No. 1, ½-in. standard steel pipe; No. 2, ⅜-in. copper tubing; 3/64-in. wall. Unrestricted steam flow on outside of tube. Diphenyloxide, 80 to 280 deg. fahr.)

over primary and secondary air temperatures for each burner. This flexibility make it possible to obtain maximum efficiency for any load. Cleaning of the apparatus is done with standard soot blowers at the economizer, while the use of clean air removes the necessity for cleaning the air heaters proper. The fan power required for duct-draft losses and the lowering of air temperature due to leakage are, of course, eliminated, while the radiation loss is cut down appreciably. Any increase in efficiency resulting will come from these last three factors.

Leakage of Diphenyloxide a Problem

The only difficulty in the entire installation was the leakage of diphenyloxide through the stuffing boxes on the circulating pump and around valve stems and sight-glass glands. Diphenyloxide has a low surface tension and low viscosity at high temperatures, and consequently requires ample provision for packing. The problem is similar to that of handling kerosene or light oils. The trouble can be substantially eliminated by increasing the amount of packing in all glands.

Enough data were taken to convince every one directly concerned that the air temperatures obtained were satisfactory. Preparations are now being made for a complete thermal study of the system, involving the determination of optimum operating conditions and heat-transfer coefficients.

It is of interest to mention briefly the work done by the Dow Chemical Company in connection with

TABLE I—PROPERTIES OF SATURATED DIPHENYLOXIDE VAPORS

Temperature		Pressure		Heat content, B.t.u. per lb.			Specific heat,	Density, lb. per cu. ft.	
Deg. fahr.	Deg. cent.	Lb. per sq. in. abs.	Vacuum, in. hg.	Liquid	Latent	Total	liquid	Liquid	Vapor
81	27.0	..	..	0	146	146	0.39	..	..
90	32.2	..	..	4	145	149	0.39	..	..
100	37.8	..	..	8	145	153	0.40	..	..
110	43.3	..	..	12	145	157	0.40	65.8	..
120	48.9	..	..	16	145	161	0.40	65.5	..
130	54.4	..	..	20	144	164	0.41	65.2	..
140	60.0	..	..	24	144	168	0.41	64.9	..
150	65.6	..	..	28	143	171	0.42	64.6	..
160	71.1	..	..	32	143	175	0.42	64.3	..
170	76.7	..	..	37	143	180	0.43	64.0	..
180	82.2	..	..	41	142	183	0.43	63.7	..
190	87.8		..	45	142	187	0.44	63.4	..
200	93.3	..	..	49	142	191	0.44	63.1	0.0012
210	98.9	..	..	54	142	196	0.45	62.8	0.0016
220	104.5	..	..	59	141	200	0.45	62.5	0.0020
230	110	0.14	29.71	63	141	204	0.46	62.2	0.0030
240	115	0.18	29.63	68	140	208	0.46	61.9	0.0034
250	121	0.23	29.53	73	140	213	0.47	61.6	0.0045
260	127	0.29	29.41	78	139	217	0.48	61.3	0.0056
270	132	0.37	29.25	82	139	221	0.49	61.0	0.0070
280	137	0.47	29.04	87	138	225	0.49	60.7	0.0080
290	143	0.58	28.82	92	138	230	0.50	60.4	0.010
300	149	0.72	28.54	97	137	234	0.50	60.1	0.012
310	154	0.91	28.17	102	137	239	0.51	59.8	0.016
320	160	1.1	27.76	108	136	244	0.52	59.4	0.019
330	166	1.3	27.36	113	135	248	0.52	59.1	0.022
340	171	1.6	26.74	118	134	252	0.53	58.9	0.026
350	177	1.9	26.14	124	134	258	0.54	58.6	0.030
360	182	2.2	25.53	129	133	262	0.54	58.3	0.036
370	188	2.5	24.92	134	132	266	0.55	58.0	0.044
380	193	3.0	23.90	140	131	271	0.55	57.8	0.050
390	199	3.5	22.88	146	130	276	0.56	57.5	0.060
400	204	4.0	21.90	151	129	280	0.57	57.2	0.068
410	210	4.6	20.65	157	128	285	0.57	57.0	0.077
420	216	5.3	19.20	163	127	290	0.58	56.7	0.090
430	221	6.2	18.4	169	126	295	0.59	56.4	0.10
440	227	7.0	15.8	154	125	299	0.59	56.2	0.12
450	232	8.0	13.7	180	124	304	0.60	55.9	0.14
460	238	9.1	11.5	186	123	309	0.60	55.7	0.16
470	243	10.2	9.2	193	122	315	0.61	55.4	0.18
480	249	11.7	6.2	199	121	320	0.62	55.2	0.21
490	254	13.0	3.6	205	121	326	0.62	55.0	0.24
496	258	14.7	0.0	208	120	328	0.62	54.8	0.26
			Lb. per sq. in. gage						
496	258	14.7	0.0	208	120	328	0.62	54.8	0.26
500	260	15.3	0.6	211	119	330	0.63	54.7	0.28
510	266	16.1	1.4	218	118	336	0.63	54.3	0.32
520	271	18	3.3	224	117	341	0.64	53.9	0.36
530	276	20	5.3	230	116	346	0.64	53.5	0.40
540	282	23	8	237	115	352	0.65	53.2	0.44
550	288	25	10	243	114	357	0.65	52.8	0.48
560	293	28	13	250	113	363	0.65	52.4	0.54
570	299	31	16	256	112	368	0.66	52.0	0.60
580	304	34	19	263	110	373	0.66	51.7	0.67
590	310	38	23	270	109	379	0.66	51.3	0,75
600	315	42	27	277	108	385	0.66	50.9	0.88
610	321	46	31	283	107	390	0.67	50.5	1.00
620	327	52	37	289	105	394	0.67	50.2	1.10
630	332	57	42	296	104	400	0.67	49.8	1.17
640	338	62	47	303	103	406	0.67	49.5	1.24
650	343	68	53	310	102	412	0.67	49.1	1.29
660	349	74	59	316	100	416	0.68	48.7	1.34
670	354	80	65	323	99	422	0.68	48.3	1.40
680	360	87	72	330	97	427	0.68	48.0	1.5
690	366	95	80	337	96	433	0.68	47.6	1.6
700	371	100	85	343	95	438	0.68	47.3	1.7
710	377	110	95	350	93	443	0.68	46.7	1.8
720	382	118	103	357	91	448	0.68	46.3	1.9
730	388	126	111	364	90	454	0.68	45.8	2.1
740	393	136	121	371	88	459	0.68	45.3	2.3
750	399	146	131	377	86	464	0.69	44.8	2.5
760	404	156	141	384	84	468	0.69	44.4	2.6
770	410	167	152	391	82	473	0.69	43.8	2.7
780	416	180	165	398	80	478	0.69	43.3	2.9
790	421	192	177	405	78	483	0.69	42.7	3.2
800	427	210	195	412	76	488	0.69	42.0	3.5
950	510	Critical temperature							

the use of diphenyloxide in its own power plant for superheating and reheating high-pressure steam. The experimental boiler had for its main aim to make high-pressure steam boilers cheaper and safer by the elimination of heavy drums wherever possible. The late Dr. H. H. Dow (3) was thoroughly convinced, from experience on high-pres-

sure tubular chemical reactors, that a boiler similar to the Benson boiler, operating at the pressure desired, instead of throttling from the critical pressure, is not only possible but is practical. In other words, a boiler intended to make 1400-lb.

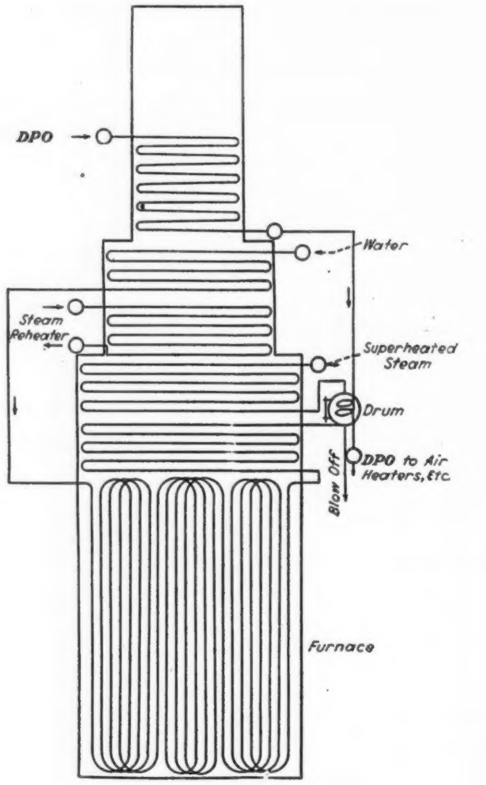


Fig. 2—Single-pass coil boiler.

steam should require boiler-feed pumps for not more than 1800 lb. pressure, rather than for 3400 lb. To accomplish this purpose without undue variations in the amount of water entering various parallel strands of tubing, careful checks were made of the pressure drops through the economizer, boiler, and superheater sections of the continuous coils to be used. To increase the heat capacity of such a tubular boiler system in order to be able to take fluctuations in demand with the assurance that no water would enter the turbine and to control the temperature of the superheated steam, a diphenyloxide boiler was combined with the steam boiler. These were so designed that heat could be transferred either from or to the diphenyloxide according to the requirements of the steam. In addition, enough diphenyloxide vapor was to be generated for reheating the steam in the turbine room between the high-pressure and the low-pressure turbines.

While the aim of this experimental boiler was to make possible the design of a power plant that would incorporate a comparatively small amount of diphenyloxide heat-interchange equipment, it was decided to make the diphenyloxide boiler as large as possible in order to obtain experience on a large diphenyloxide boiler unit and to combine it with the smallest high-pressure steam boiler and turbine equipment that would be practical.

Both Working Toward Same Goal

However, when one compares the ultimate object of the type of a boiler toward which these experiments were working and the new developments that have been made in the line of high-pressure boilers since the time when this experimental boiler was planned back in 1926, it is quite obvious that the industry as a whole is coming toward this same goal. Work has been suspended on this boiler for the present, until the demand for power increases.

The experimental boiler was to develop into a large single-pass high-pressure steam boiler with the equivalent of a steaming economizer for practically all of its boiler surface. (See Fig. 2.) A small portion of the water that would not be evaporated in these tubes would be evaporated with diphenyloxide vapor in a drum in which any scale would be formed on the outside of the diphenyloxide coils and settle out to be blown off. The steam would leave this heat-interchanger drum in a superheated condition at a temperature so regulated that the final temperature would be the desirable value regardless of the rating of the boiler.

Diphenyloxide liquid would be heated and partly evaporated in another steaming economizer which would cool the gases in the last pass. The diphenyloxide vapor would be used for drying the steam and controlling the superheat and reheat of the steam, while the hot liquid would be used for preheating air and boiler-feed water and for heat storage, as desired.

In this way one can use the excess heat contained in flue gases, over what is required for preheating the air, for preheating some water.

In order to design equipment using these high-boiling compounds, the first requirement is to have

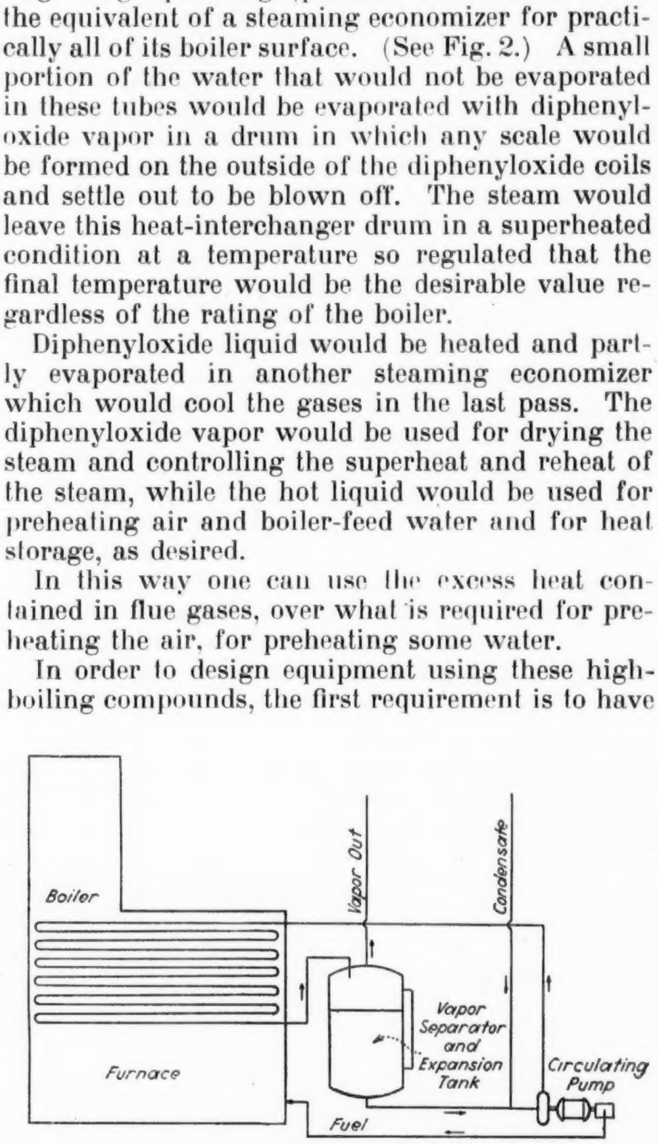


Fig. 3—Industrial diphenyloxide vapor system.

the necessary thermal data available. During the past six years a considerable amount of work has been done by the members of the research staff of the Dow Chemical Company to determine and calculate the physical and thermal properties of diphenyloxide, a good part of which is summarized in Table 1. Fig. 1 gives the results of heat-transfer determinations between liquid diphenyloxide and condensing steam. The results were calculated on the basis of the external surface of the pipe as speci-

fied. Other thermal data obtained by others for diphenyl are given in the references (4, 5, 6, 7, 8, 9, 10).

Diphenyloxide is so fluid at higher temperatures that the temperature differential between the heated surface and the boiling liquid is exceedingly low.

Measurements that were made with an electrically heated iron wire while the temperature was determined by measuring its resistance while being heated indicate that there is only a differential of 17 deg. fahr. between the ⅛-in. iron wire and the boiling liquid at a rate of heat transfer of 50,000 B.t.u. per hour per square foot.

All this indicates that the heat transfer, both from the liquid and to the liquid, is reasonably

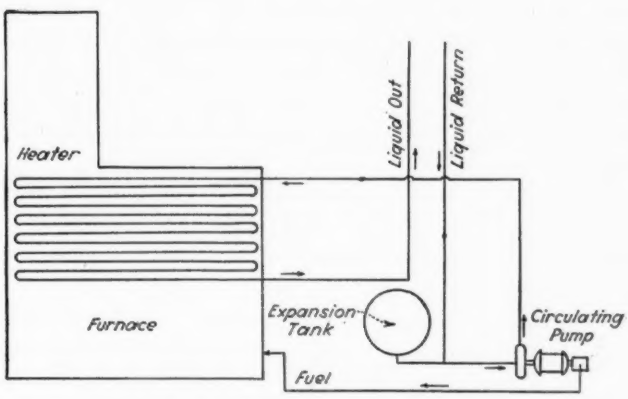


Fig. 4—Industrial diphenyloxide liquid system.

high and sufficiently good to be satisfactory for commercial work.

Boilers Advised for Diphenyloxide

There are two types of boilers recommended for the use with diphenyloxide. The first is a boiler with natural circulation in which the only requirement is that the boiler be designed for very free circulation with a high head between the vapor-separating drum and the furnace. This makes use of the air-lift effect of the vapor as much as possible. If such a boiler is designed with a sufficiently large furnace to keep the heat transfer down to approximately 10,000 B.t.u. per square foot per hour of total surface, no trouble should be encountered. In fact, back in 1926 a boiler was operated under more severe conditions with natural circulation and with perfect satisfaction. However, two tubes were plugged up at first when it was attempted to push the heat transfer to ten times the normal rating. Another time, when operation was attempted at 35 lb. pressure instead of at 125 lb., the large volume of vapor produced could not escape from the heated section fast enough. The tube became vapor bound and plugged with carbon, and it burned up. In each of these cases it was noted that no large amount of diphenyloxide escaped into the furnace. Carbon formed as fast as the tubes oxidized, plugging the holes tight.

A forced-circulation boiler can be constructed to have the minimum of inventory and nothing but long tubular economizer units for heat-absorbing surfaces. The maximum amount of vapor that could e·er escape from such a tube into the boiler setting can readily be taken care of by the stack, so that such a boiler can be installed almost anywhere. The design as indicated in Figs. 3 and 4 requires only that the circulating pump be coupled with the fuel feed so that no fuel is sent to the furnace except when the necessary circulation is obtained.

Combining the information so far obtained on these heat-transfer materials with the fact that the price of these materials has decreased continually as their use was increased, one can confidently look ahead to further progress along these lines with an ever-widening list of applications.

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Liability of Heating Company for Negligence in Making Steam Supply Connection to Building

(*Continued from page 37*)

"The evidence seems to us to warrant the conclusion, * * * that the nipple, that is, the threaded end of the two and one-half inch pipe, was screwed into the bushing of the valve only about one-quarter of an inch; that this was unsafe and poor workmanship; that a proper inspection * * * would have shown that the pipe was not sufficiently screwed into the bushing to constitute a safe and workmanlike connection; and that this improper maintenance of the connection was the negligence causing the steam to escape. * * * The judgment, * * * against the heating company is affirmed." (293 Pac. 466).

So that was that. And the heating company was called upon to assume a substantial judgment growing out of the carelessness of some of its workmen in making the connection to the building. Of course, the case was decided strictly on the facts involved, and even a slight change in these might have resulted in a different judgment.

However, the facts and holding, when taken together constitute a striking illustration of the possibilities for liability accruing to a heating company because of slipshod, or under-inspected work of this kind. Certainly, care, and then more care, may well be the rule to the end that danger from future liability, because of negligence in performance, may be guarded against insofar as possible.

The Logarithmic Mean Temperature Difference

All problems in heat transfer involve a difference in temperature between the heat receiving medium and the heat absorbing medium. This difference in temperature or temperature head is sometimes maintained constant, as in a boiler furnace where heat is constantly being supplied to the furnace and taken away in the boiler. In most cases, however, the temperatures of the two media change with the interchange of heat, and the temperature difference available for the transfer of heat is constantly changing.

The initial temperature difference (a) and the final temperature difference (b) being known, the average temperature difference MTD may be determined from the equation:

$$\text{Mean temperature difference} = \frac{a - b}{\log_e \frac{a}{b}}$$

This value is known as the logarithmic mean temperature difference. When the value of (b) is greater than one half of (a), the logarithmic mean is not greatly different than the arithmetic mean $\frac{a + b}{2}$. For values of (b) less than one half (a) the logarithmic mean should be used.

Figs. 1 to 4 show typical absorption curves for various apparatus.

Fig. 1 shows an absorption curve for a boiler. The temperature of water in the boiler remains constant while the gas temperatures decrease along its path of flow.

Fig. 2 shows temperature curves for an economizer using counterflow. Due to its greater heat capacity the temperature of the water does not rise as rapidly as the temperature of the gases decreases.

Fig. 3 shows temperature curves for an air heater using counter-flow. The specific heat of air is less than the specific heat of flue gases, and also the mass of air passed through the heater, unless the air is used for other purposes than combustion, is less than the mass of the gases. The air temperature therefore, rises more rapidly than the gas temperature drops.

If parallel flow is used the temperature curves would be as shown in Fig. 4. The principle of counter-flow results in a greater mean temperature difference between the air and the gas.

The chart on the opposite page has been prepared from the equation given. The values of (a) the initial temperature difference are given on the vertical scale. The values for (b) the final temperature difference do not appear on the chart but are used only to determine the ratio $\frac{a}{b}$.

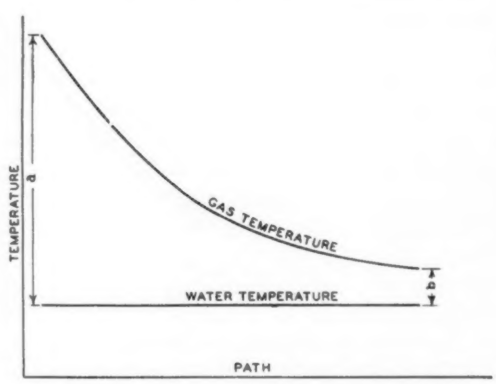

Fig. 1—Heat absorption curve for boiler.

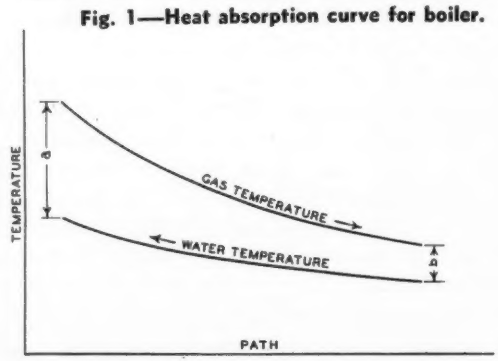

Fig. 2—Heat absorption curve for economizer (counter flow).

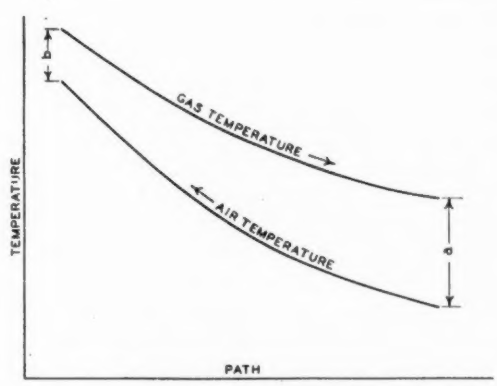

Fig. 3—Heat absorption curve for air heater (counter flow).

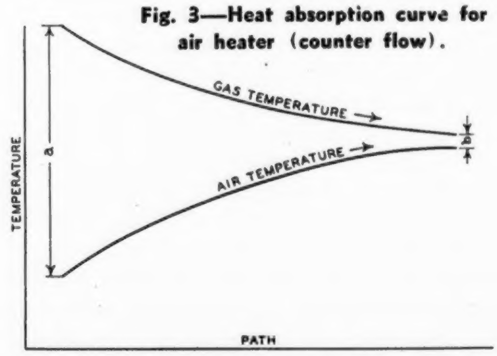

Fig. 4—Heat absorption curve for air heater (parallel flow).

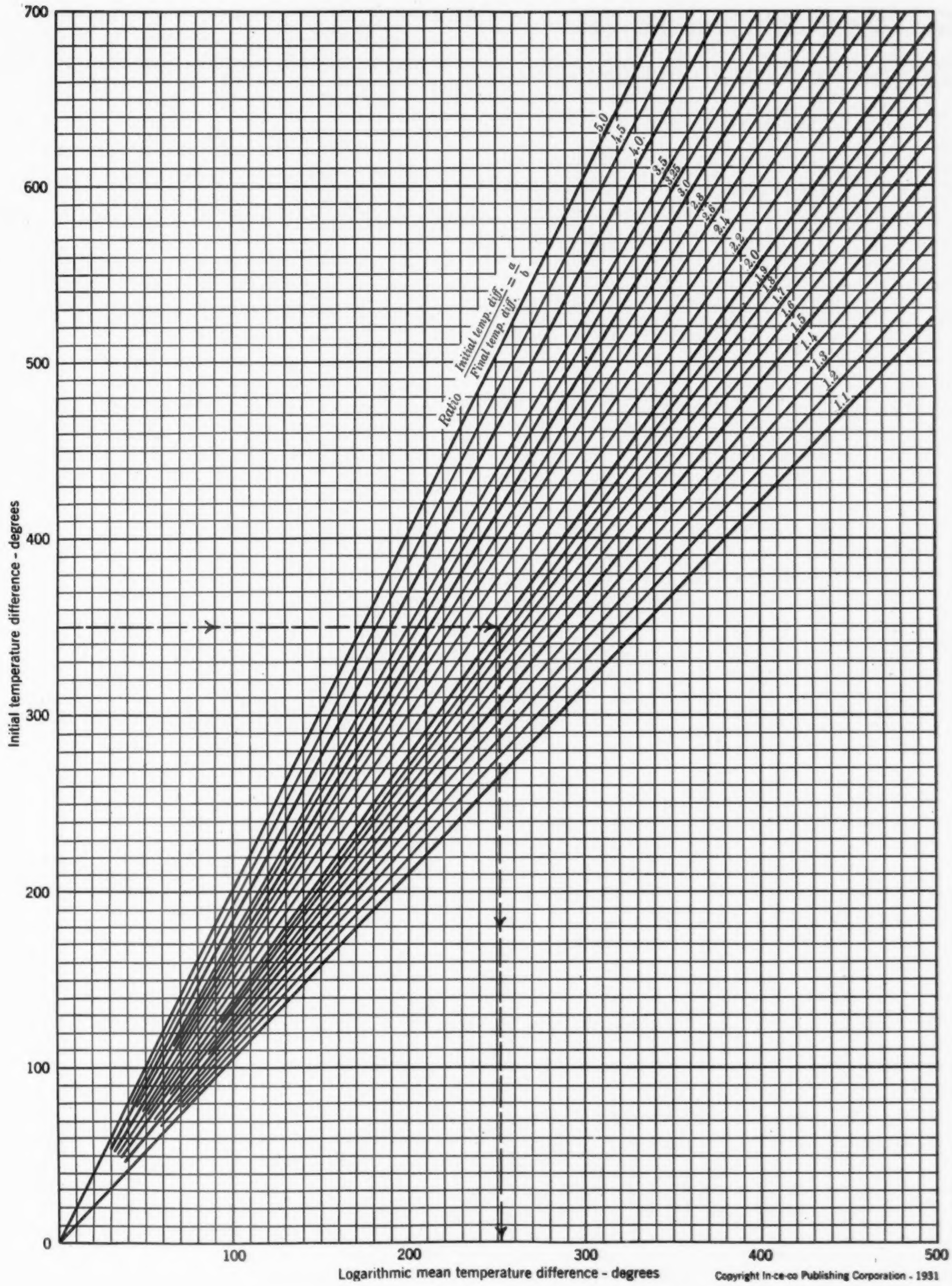

CHART FOR DETERMINING THE LOGARITHMIC MEAN TEMPERATURE DIFFERENCE

No. 29 of a series of charts for the graphical solution of steam plant problems.

The Most Efficient Power Station in Great Britain

(*Continued from page 36*)

missioners, and most people in authority, have obviously the fixed idea that no power station can be really efficient unless it has cost about $15,000,000 to $75,000,000 and is about 150,000 to 750,000 kw. in size. This idea is of course erroneous as a 50,000 kw. plant can be practically as efficient in every way as a 500,000 kw. plant. In Great Britain, with its small area and dense population, it is, in my opinion, much better general national policy, for various reasons, to have say five stations of 100,000 kw. instead of one at 500,000 kw. Now Kearsley has followed the example of Padiham in smashing the chief so-called argument against the smaller plant, lower net efficiency, by taking the lead in Great Britain over stations four or five times as big. The conditions of course in the United States are different, but that mere size of station necessarily means high net efficiency and the best commercial practice is ridiculous, and American power station practice seems to me to be affected to some extent with the same disease, in spite of the larger consumption of electricity. Kearsley, however, adds insult to injury by not only being small but also simple in design and operation, without all kinds of equipment regarded as essential to the best results.

In my own experience with industrial boiler and power plant I generally found that it was a paying policy from the net point of view to operate a boiler plant on easy lines, that is within reason. The inherent objection in a super-power station to working boilers by this method at less than say 350 lb. pressure and 7.5 lb. evaporation per sq. ft. heating surface, is of course increased capital cost but it would seem this factor has not been studied sufficiently.

At Kearsley the cost is also low, being a total of about $4,338,000 or $68.00 per kw. of installed plant capacity, which includes 42 acres of land. Many power stations in Great Britain exceed these figures, being in some cases as high as $96.00 per kw.

Capital cost, of course, is difficult to compare because of variation in local conditions, and, generally speaking, Kearsley is probably somewhat favorably situated as compared with most power stations in Great Britain in regard to cost of land, site away from a town, load factor above the average, and comparatively good coal, being in a well-known colliery area.

The achievement of 23.84 per cent continuous thermal efficiency is especially notable since Kearsley was not built with any idea of record breaking in this connection, but purely as a commercial proposition to suit the individual conditions. Thus Mr. M. H. Adams, whom I have to thank sincerely for information and all the photographs reproduced herewith, points out they could easily have attained a better efficiency by using high steam pressures and temperatures but, in their opinion, at the sacrifice of freedom from trouble and nuisance.

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Lightning Protection For High Stacks

Factory stacks extending high into the sky above the surrounding buildings reach up into the atmosphere between the electrically charged clouds and the earth. When the accumulated cloud charges are pierced the air insulation is broken down and a lightning stroke results. The resistance is usually least where the chimney pierces this blanket of air insulation, thus often providing a pass for the bolt in its passage to the earth. These high factory stacks are therefore particularly vulnerable to lightning strokes.

There have been several cases during the past years of spectacular and extensive damage to stacks of Factory Mutual mills. In June 1923 a bolt struck a well constructed and substantial stack at the plant of the Canadian Shredded Wheat Company, Ltd., Niagara Falls, Ontario. The loss resulting from the lightning exceeded $8,000, well over half of which represented the damage to the chimney alone. Longer ago in 1890 the stack of the Clarkburg Company's plant in East Newark, New Jersey, suffered damage of over $3,000 from the same cause. Only last year at the National Enameling & Stamping Company's plant at Laurel Hill, New York, lightning damaged the stack so badly that the top ten feet had to be entirely rebuilt at a cost of $2,600. Every summer adds many cases of lightning damaged chimneys to the already long list.

The inspection department of the Factory Mutuals several years ago made a study which showed that the average damage to chimneys equipped with lightning rods was less than one-tenth of that to chimneys which were not equipped. Rods tend to prevent damage under certain conditions by facilitating the neutralization of the earth and cloud charges before they accumulate to a dangerous extent. And when a heavy charge does get loose they are usually able to carry it away without harm to the chimney. Consequently, although they are not an absolute preventive, they much reduce the probability of heavy damage.

Conductors should be preferably of copper and should have a carrying capacity at least equal to a No. 00B & F Gauge, and when tape is used it should not be smaller than 1 in. x 3/32 in. Chimneys less than sixty feet high should have at least one or preferably two rods, while higher chimneys should have at least two rods.

An efficient ground at the lower end of the rods is important. The best and generally most convenient ground is an underground watermain but where these are not available buried copper plates are the alternative.

NEWS

Pertinent Items of Men and Affairs

Stoker Manufacturers' Association Holds Annual Meeting

The Stoker Manufacturers' Association held its annual meeting October 26-28 at Seaview Golf Club, Absecon, N. J.

J. G. Worker, President, called attention to the social effects of the increasing use of stokers, including reduction of smoke and sulphur dioxide discharged into the atmosphere, improvement in boiler room working conditions and personnel, and changes in the coal mining industry as the result of the creation of new markets for the sizes of coal fired by the smaller stokers.

T. A. Marsh, forecast the development of Heat Service in metropolitan areas by companies that would install small stokers and supply complete service to operate them. It will be as easy, he said, to keep the stoker hoppers filled and remove the ashes as it is to ice a refrigerator in the home.

John Lovett, General Manager of the Michigan Manufacturers' Association, was guest speaker.

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The Permutit Company, 440 Fourth Avenue, New York City, has announced the return of Mr. Francis D. West as district sales manager of its Buffalo office with headquarters at 717 Brisbane Building, Buffalo, N. Y. Mr. West was associated with The Permutit Company from 1918 until 1930 and then served as manager of sales of the Paradon Company. His return to The Permutit Company is effective as of October 1, 1931.

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Albert Jefferson Sayers, noted Link-Belt engineer, sixty-one years old, died at his home in Chicago on October 11.

Mr. Sayers was head of the Coal Tipple and Coal Washery Department of Link-Belt Company, Chicago. He was well known throughout the entire coal industry, having designed and built numerous plants for the handling and preparation of coal in all parts of the country, and was recognized as one of the leading designers of this type of equipment.

In the thirty-two years of his affiliation with Link-Belt Company, Mr. Sayers came to be a recognized authority in the mechanical handling, screening and washing of coal. He was a member of the A. S. M. E., the Manufacturers Division of the American Mining Congress and other engineering organizations.

General Water Treatment Corporation Acquires American Zeolite Corporation

The business of the American Zeolite Corporation, manufacturer of Decalso, a synthetic base exchange material used in the softening of water, was acquired October 1 through stock ownership by the General Water Treatment Corporation. The business will be operated by the American Zeolite Corporation as a unit of the General Water Treatment Corporation with offices at 440 Fourth Ave., N. Y.

The General Water Treatment Corporation was organized in 1930 and at that time acquired The Permutit Company and the Ward-Love Pump Corporation. Through purchase by The Permutit Company, it took over the zeolite and lime soda water softening and filter business of the Paige & Jones Chemical Company.

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The Riley Stoker Corporation, Worcester, Mass., recently announced the following appointments: F. E. Fleming as sales engineer at Chicago office; R. L. Sauer as district manager at Detroit office; M. L. Cornelious as district manager at Cleveland office, I. W. Lachman as sales engineer at New York office, W. J. Ehmer as sales engineer at Philadelphia office.

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Purdue University has announced, through the Engineering Extension Department, that its Seventh Annual Conference on Welding will be held at Lafayette, Indiana, on December 10 and 11. The meeting will consist of lectures, demonstrations and exhibits.

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Foster Wheeler Corporation, 165 Broadway, New York City, has announced the appointment of Mr. H. L. Robinson as general sales manager of the Foster Wheeler Corporation, effective September 1. Mr. Robinson has long been associated with Foster Wheeler interests, having joined the Wheeler Condenser and Engineering Company prior to the formation of Foster Wheeler Corporation.

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The Dunbar Engineering Company, New York sales representative for The Edward Valve and Manufacturing Company of East Chicago, Ind., announces the opening of a Philadelphia office in the Witherspoon Building, Philadelphia, under the management of Mr. Lee W. Tremblay.

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The Union Chain & Manufacturing Company, Sandusky, Ohio, has announced the appointment of Mr. C. H. Upson as its Cincinnati representative with offices at 1012 Traction Building, Cincinnati.

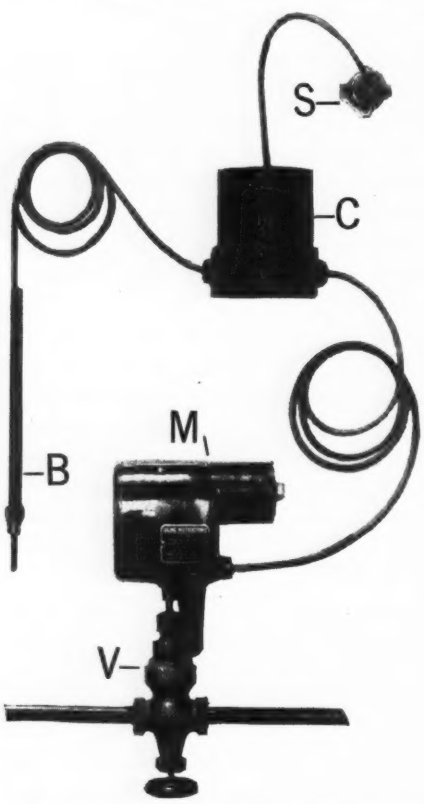
NEW EQUIPMENT

of interest to steam plant Engineers

Automatic Temperature Control

A new all-electric temperature control system has been introduced by Uehling Instrument Company, Paterson, N. J.

Practically every industry uses heat in one form or another. Automatic temperature control cuts costs in many ways; 1st—by holding the temperature steady it saves fuel; 2nd—by eliminating spoilage there is no waste of material, labor or time; 3rd—the time and thought required for manual control can be utilized in other directions; 4th—by increasing the efficiency of the process involved, more work can be turned out per unit, thereby saving overhead; 5th—by



insuring a constant high standard of quality, thereby reducing sales resistance for the product manufactured.

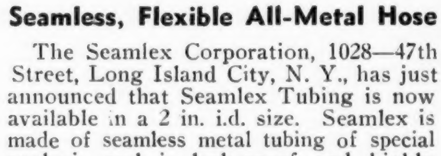
No piping or tubing of any kind is required when installing the new all-electric temperature control. The Control Unit C may be screwed to the wall in any desired location regardless of distance. The Bulb B is inserted in the medium, the temperature of which is to be controlled. The Bulb is supplied with fixtures to permit fastening it in any suitable manner under the conditions used. The only connection between the Bulb B and the Control Unit C, is one ordinary two-wire electric light cord. An electrically operated Valve V which controls the heat input and which is actuated by the Control Unit C, may be furnished in various styles and sizes to meet the conditions involved. The Valve V is connected with the Control Unit C by means of a three-wire electric cord. The only other connection is an electric cord between the Control Unit C and an ordinary electric light socket S. The ease with which this control can be installed, combined with its extreme accuracy and reliability, are very important features of this very simple type of equipment.

The control can be made with almost any degree of sensitivity. If desired, the temperature Bulb B can be made so sensitive that a change in its temperature of only a few hundredths of one degree above or below the fixed setting of the Bulb will be enough to actuate the Control Unit. There are no adjustments, each Temperature Bulb is adjusted for the desired temperature at the factory. Each Bulb is guaranteed to maintain its original setting indefinitely and without the slightest change in accuracy. Extra Bulbs for different temperatures can be obtained.

Seamless, Flexible All-Metal Hose

The Seamlex Corporation, 1028—47th Street, Long Island City, N. Y., has just announced that Seamlex Tubing is now available in a 2 in. i.d. size. Seamlex is made of seamless metal tubing of special analysis and is leak-proof and highly flexible. It can be used for handling gases, steam or liquids. There are twelve sizes ranging from 1/16 in. i.d. with a bursting pressure of 10,000 lb. per sq. in. to the newly developed 2 in. i.d. size with a bursting pressure of 600 lb. per sq. in. Where necessary it can be reinforced to withstand considerably higher pressures.

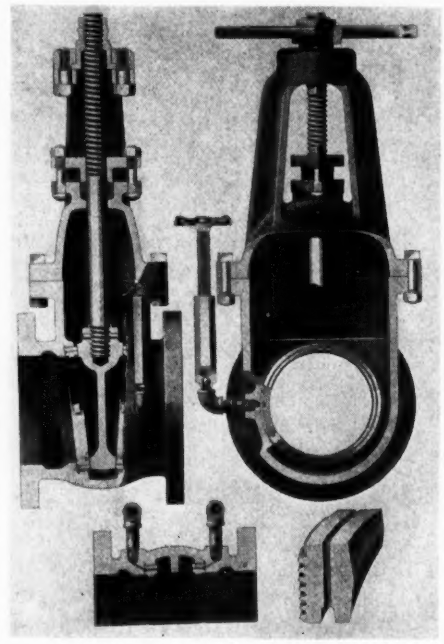
Among the various types of Seamlex Hose are the following: *Open Pitch Seamlex*—a flexible seamless tube suitable for vibrations, occasional bending, radiations, etc.; *Close Pitch Seamlex*—a flexible seamless tube suitable for high pressure, frequent bending, swivel joints, bellows, etc.; *Seamlex with Copper Braid* and male pipe thread fitting, suitable for low and medium pressures and little strain near fittings; *Seamlex with Steel Braid* and female pipe thread fitting, suitable for high pressure and little strain near fittings; *Seamlex with Steel Strip Braid* and union, suitable for high internal pressure and exterior wear; *Seamlex with Interlocked Armor* for low or high pressure, for cold or heat, suitable for rough usage; *Seamlex with Asbestos Braid* used as steam hose. Insulation preserves heat and protects against burns.



Seamlex can be furnished with any standard type of fitting or special fittings if desired. No packing of any kind is used. For handling high temperature gases or liquids, it is covered with insulation. For unusual conditions of service, Seamlex can be made up special.

Gate Valve with Lubricant Seal Between Heating Surfaces

Reading-Pratt & Cady Company, Inc. Bridgeport, Connecticut, has recently announced the Lubrotite Gate Valve incorporating the lubricant-seal principle of tight seating. In this valve there is a unique duct system for introducing a lubricant-seal between the seating surfaces. The valve is sealed tight even though the seating surfaces have become damaged by scratches, deposits, or corrosion in the line. Other advantages of the valve are: (1) It operates from 25



to 50 per cent easier than non-lubricated valves. (2) The seating surfaces protected by film of lubricant. They will not become corroded, scratched, or injured as easily as non-lubricated valves. (3) It frees set wedge—lubricant-seal separates wedge from seats slightly, freeing wedge that has become set from a long period of service. (4) It gives exceptionally long service.

This valve is recommended for boiler feedwater lines, boiler blow-off, water systems, chemical lines, paper mill service, and other services requiring an absolutely dependable valve.

The Lubrotite Valves are made in both Pratt & Cady Standard and Extra Heavy Iron Body Patterns, and in Reading Electric Cast Steel. The general dimensions are the same as the non-lubricated valves, so Lubrotite Valves can be used for replacement service without changing the piping system in any way.

All valves seat absolutely tight without the use of the lubricant-seal and can be used, if desired, as regular non-lubricated valves.

Lubricant-seals are supplied for various services—air, gas, water, chemical, petroleum products, etc. The Lubricant-seals are packed in convenient pocket sized boxes—24 cartridges to a box. Only a small amount of lubricant is needed for an application.

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Steam Turbine Operation

By William J. Kearton

THIS book while relating primarily to English turbines and practice is of a highly practical and informative character and can be read to advantage by American engineers interested in the design and operation of turbines.

The introductory chapters deal with the installation of turbines and with the principles involved in shaft alignment. The proper heating and drainage of large steam turbines and the allowance for differential expansion during warming up or change of load are fully discussed. Then follows an account of the different types of shaft glands and the arrangements made for sealing them under varying conditions of operation, with an important section on lubrication and the treatment of lubricating oils. The centrifugal governor and its relay gear and the hydraulic type of governor gear are fully described for their importance to a proper understanding of such matters as hunting, sensitiveness, etc.

The operating engineer will particularly appreciate the chapters dealing with the preparations for starting and stopping turbines and their inspection and overhaul, which precede the helpful information on the causes of failure in Chapter VIII.

The fundamental principles underlying the testing of steam turbines, the statement of results, and the methods employed are discussed at considerable length, together with many notes of value on temperature measurement and the measurement of power.

This book is 5¾ by 8¾ overall and contains 300 pages. The price is $3.75.

Who's Who in Engineering

Edited by Winfield Scott Downs

THIS is the third edition of this valuable directory of engineers. In revising the second edition, published in 1925, the Advisory Committee, appointed by the American Engineering Council, adopted the following rules governing the selection of names: (a) Engineers of outstanding and acknowledged professional eminence. (b) Engineers of at least ten years' active practice, at least five years of which have been in responsible charge of important engineering work. (c) Teachers of engineering subjects in colleges or schools of accepted standing who have taught such subjects for at least ten years, at least five years of which have been in responsible charge of a major engineering course in such college or school.

The new edition contains 12,000 names with a complete chronological record in each case. Reference is facilitated by a supplementary geographical index.

This volume is 6 by 9 overall and contains 1600 pages. The price is $10.00.

Steam Power and Internal Combustion Engines

By Dudley P. Craig and Herbert J. Anderson

THE subject matter of this book includes descriptions of essential up-to-date mechanical equipment, expositions of theory underlying its construction and operation, and modern methods of adapting it to power units. The historical development has been touched upon where it has been considered effective in increasing the student's interest.

No attempt has been made to include the electrical equipment of power plants, even though this equipment forms a very important part of such plants. The simpler electrical circuits of automotive engines, however, are described, this being essential to a complete understanding of the operation of these prime movers. Principally as an aid to students who have not studied thermodynamics, there is provided a chapter reviewing the fundamental principles of that subject. To be most effective, a course using this book should be either preceded or accompanied by heat engineering laboratory practice.

The solution of many typical examples has been given to aid in the explanation of methods of making power calculations. Problems follow chapters that contain calculations.

A more specific idea of the content of this book is given by the following list of chapter headings: Fundamentals of Power Plants; Principles of Thermodynamics; Fuels and Combustion; Steam-Power Boilers; Stokers and Coal Handling; Equipment for Burning Pulverized Coal, Oil, Gas and Wood; Draft Equipment and Air Preheaters; Steam Superheaters and Separators; Feedwater Heating and Treatment; Steam-Engine Study; Special Designs of Steam Engines; Steam Turbines; Condensing Equipment; Pumping Equipment; Internal Combustion Engines.

This book is 6¼ by 9¼ overall and contains 482 pages. The price is $4.00.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Arc Welding

"Arc Welding in Industry" is the title of new catalog GEA-995A featuring diverse applications of arc welding for various types of fabrication in the principal industries. Numerous illustrations show the equipment in use, and various sizes and types of arc welding equipment are also illustrated and described. 40 pages and cover, 8 x 10½—General Electric Company, Schenectady, N. Y.

Coal Pulverizer

The Whiting Table-Roller Pulverizer is described and illustrated in a new pamphlet, Bulletin No. 12. A wash drawing showing a section through the pulverizer illustrates its construction and indicates the flow of air and coal. The illustrations include several installation photographs. A list of installations is also given, which includes applications for pulverizing coal and other materials. 8 pages, 8½ x 11—Whiting Corporation, Harvey, Ill.

Electric Flow Meters

Catalog 2002 describes Brown Electric Flow Meters. The first section illustrates and describes the various applications of flow meters. Later sections describe how flow meters operate, and present a detailed description, together with illustrations, of the elements comprising the Brown Electric Flow Meter, which operates on the inductance bridge principle. The final section of the catalog describes other Brown instruments and meters. 56 pages and cover, 8 x 10—The Brown Instrument Company, Wayne and Roberts Aves., Philadelphia.

Multiple Circulation Boiler

The C-E Multiple Circulation Boiler is described and illustrated in Bulletin MC-1, which also includes specifications of the several types in which this boiler is offered. This boiler, which is of the four-drum, bent-tube type, three drums at the top and one at the bottom, has a unique arrangement of tubes, which is intended to provide adequate circulation and correct steam liberation under the most severe conditions of service. The double circulation effect is secured by interconnection of the bottom drum with the first two upper drums, thus splitting the circulation. This boiler is available in a wide range of sizes and for various pressures. 4 pages, 8½ x 11—Combustion Engineering Corporation, 200 Madison Ave., New York, N. Y.

Potentiometer Pyrometer

"Micromax" is the name of an improved, fully automatic potentiometer pyrometer, described in Catalog No. 87. Extreme sensitivity and accuracy are claimed for this pyrometer, which is of an entirely new and different design. Previous designs of potentiometer pyrometers made by this company are convertible into Micromax Pyrometers at nominal cost. The details of Micromax are fully described and illustrated, and its various applications are indicated. All models of Micromax are now in production and are available on the usual schedule of deliveries. 44 pages and cover, 8 x 10—Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia.

Rotameters for Liquids & Gases

The rotameter, a measuring device for indicating the rate of flow of gases or liquids in a pipe line, is described in Bulletin No. 6-F, Supplement 1. Two types of rotameters are covered, namely, the "Thruflow" and "Orifice" types, the former being applicable to small medium sized pipe lines arranged either horizontally or vertically, and the latter for horizontal pipe lines, carrying large quantities of gas or liquid. A table of specifications and prices is given. 4 pages, 8 x 11—Schutte & Koerting Company, 12th and Thompson Streets, Philadelphia, Pa.

Short-Center Belt Drives

"VIM Short-Center Drives" is the name of a new belt treatise compiled by the Engineering Research Staff of E. F. Houghton & Company. It is an entirely new treatment of efficient short center drives. The book contains charts, tables, and engineering data on 5,000 standard VIM EFFICIENCY DRIVES ranging from 5 to 100 hp. The book is built entirely around VIM special mineral tanned leather belting. This book, originally published for use by Houghton's technical field men to assist them in discussing and working out transmission problems with engineers, is not for general distribution, but copies will be delivered to executives and engineers directly interested in transmission who will send in their requests in writing on their company letterheads. 152 pages and cover, 8½ x 11—E. F. Houghton & Co., Philadelphia, Pa.

Steam and Air Trap

The new Lindstrom Multi-Port Steam and Air Trap is described in a bulletin just issued. This trap consists of only four parts, the body, cover, float and valve. The operation of the valve is described and illustrated and specifications and price list are given. This trap is made in three sizes for pressures from 1 to 100 lb. 4 pages, 4 x 9¼—Strom-Port Manufacturing Co., Inc., 215-217 South Third Street, Allentown, Pa.

Steam Generating Units

Riley-Badenhausen Boilers, Water-Cooled Furnaces and Superheaters are described in a new catalog which also features the combination of these elements in conjunction with Riley pulverized fuel equipment and Riley, Harrington and Jones stokers, in the form of complete steam generating units. Detailed information and application drawings covering installations of these steam generating units are included, together with a description of the company's plant facilities, particularly those employed in the manufacture of boilers. 70 pages and cover, 8½ x 11—Riley Stoker Corporation, Worcester, Mass.

Stoker Tests

Tests of the Whiting Stoker with fourth and fifth vein Indiana coals, recently conducted at Purdue University, are described in a new pamphlet, which indicates the method of test procedure and presents data in table and chart form on the results secured. The tests were made to determine the suitability of the stoker for burning the poorer grades of Indiana coal, and involved both reliability and maximum capacity tests. 16 pages, 8½ x 11—Whiting Corporation, Harvey, Ill.

Water Cooling Equipment

Spray cooling ponds, spray cooling towers, deck cooling towers, spray louvre fencing and spray nozzles for all industrial applications are described and illustrated in Bulletin No. 6-E. Condensed information on the selection of the right cooling system for a particular purpose is given in the first part of the bulletin. Specifications of the equipment, together with technical data covering applications, are given, as are illustrations of installations in various industries. 36 pages, 8½ x 11—Binks Manufacturing Co., 3114-40 Carroll Ave., Chicago, Ill.

X-Ray Examination of Welded Pressure Vessels

An article reprint describing the X-ray method of testing as specifically applied to welded boiler drums. The technique of this method of weld testing, prescribed in the new A. S. M. E. Code, is discussed comprehensively, and a description of the equipment required is given. 8 pages, 8½ x 11—Combustion Engineering Corporation, 200 Madison Ave., New York, N. Y.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION

200 Madison Ave., New York

Boiler, Stoker and Pulverized Fuel Equipment Sales

BOILER SALES

Orders for 827 boilers were placed in August according to reports submitted to the Bureau of the Census by 73 manufacturers.

Month	1930 Number	1930 Square feet	1931 Number	1931 Square feet
January	942	1,081,749	598	576,723
February	873	938,906	516	622,343
March	977	1,263,709	630	664,784
April	1,017	1,070,093	689	825,203
May	1,283	1,329,748	658	603,401
June	1,360	1,588,553	818*	677,434*
July	1,309	1,410,096	816	687,058
August	1,371	1,356,751	827	594,698
Total (8 mo.)	9,132	10,039,605	5,552	5,251,644
September	1,254	1,282.388		
October	1,189	851.525		
November	777	709.322		
December	814	587,053		
Total (Year)	13,166	13.469.893		

* Revised.

TOTALS FOR FIRST 8 MONTHS AND NEW ORDERS, BY KIND, PLACED IN AUGUST, 1930-1931

Kind	1930 No.	1930 Sq. ft.	1931 No.	1931 Sq. ft.	August, 1931 No.	August, 1931 Sq. ft.
Stationary: Total	8,941	9,087,450	5,428	4,848,179	822	588,556
Water tube	828	4,249,557	502	2,133,292	53	196,304
Horizontal return tubular	646	883,615	344	432.772	44	57,712
Vertical fire tube	830	255,567	427	118,970	43	11,971
Locomotive, not railway	122	102,528	71	64,184	8	7,551
Steel heating	5,390	2,398,947	3,527	1,573,483	606	242,923
Oil country	796	905,474	309	348,725	31	36,109
Self contained portable	317	215,670	203	151,388	29	31,851
Miscellaneous	102	73,092	45	25,365	8	4,135

MECHANICAL STOKER SALES

August stoker sales, reported to the Bureau of the Census by the 11 leading manufacturers, totaled 132 stokers of 31,171 hp.

Year and Month	TOTAL No.	TOTAL H.P.	INSTALLED UNDER Fire-tube boilers No.	Fire-tube boilers H.P.	Water-tube boilers No.	Water-tube boilers H.P.
1929						
Total (First 7 mo.)	998	358,418	379	57,841	619	300,577
Total (Year)	1,716	599,585	706	102,515	1,010	497,070
1930						
January	53	13,198	24	2,872	29	10,326
February	73	22,648	26	3,732	47	18,916
March	89	32,403	45	6,128	44	26,275
April	108	35,903	46	6,984	62	28,919
May	96	31,956	41	5,703	55	26,253
June	151	47,803	70	10,100	81	37,703
July	150	37.761	83	11,434	67	26,327
August	115	29,988	61	10,587	54	19,401
Total (8 mo.)	835	251,660	396	57,540	439	194,120
September	128	42.899	71	9,186	57	33,713
October	92	38,276	46	5,148	46	33,128
November	71	21,103	41	5,731	30	15,372
December	53	11,726	35	5,307	18	6,419
Total (Year)	1,179	365.664	589	82,912	590	282,752
1931						
January	85	25,902	40	6,719	45	19,183
February	67	14,249	37	5,326	30	8,923
March	63	17,993	27	4,509	36	13,484
April	65	18,723	32	5,192	33	13,531
May	80	23.646	29	4,341	51	19,305
June	111	29,889	55	8,519	56	21,370
July	101	20,735	58	8,283	43	12,452
August	132	31,171	59	8,318	73	22,853
Total (8 mo.)	703	181,908	337	51,207	366	130,701

PULVERIZED FUEL EQUIPMENT SALES

August orders for coal pulverizers as reported to the Bureau of the Census aggregated 8 pulverizers having a total capacity of 29,250 lb.

Year and Month	STORAGE SYSTEM PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent	DIRECT FIRED OR UNIT SYSTEM PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent
FOR INSTALLATION UNDER WATER-TUBE BOILERS														
1931														
January	2	2	..	60,000	1	51,177	704,000	8	4	4	40,500	9	42,970	412,675
February	1	..	1	40,000	1	29,100	375,000	2	2	..	8,000	1	7,570	75,000
March	2	2	..	60,000	..	.....	......	13	13	..	122.000	8	93,960	1,404,000
April	2	2	..	60,000	1	34,300	592,000	9	8	1	49,250	6	46,300	538,200
May	..	..	..	.....	..	.....	......	..	..	..	.....	..	.....	......
June	..	..	..	.....	..	.....	......	14	6	8	59.360	11	56,080	530,290
July	..	..	..	.....	..	.....	......	11	8	3	114,600	8	117,000	1,088.980
August	..	..	..	.....	..	.....	......	4	4	..	25,000	4	17,000	137,250
Total (8 mo.)	7	6	1	220,000	3	114,577	1,671,000	61	45	16	418,710	47	380,800	4,186,395
FOR INSTALLATION UNDER FIRE-TUBE BOILERS														
1931														
January	..	..	..	.....	..	.....	......	6	..	6	6.000	6	7,500	53.350
February	..	..	..	.....	..	.....	......	3	..	3	2,250	3	3,000	22,350
March	..	..	..	.....	..	.....	......	2	1	1	2,750	1	3,004	22.500
April	..	..	..	.....	..	.....	......	1	..	1	4,000	2	6,700	45,000
May	..	..	..	.....	..	.....	......	3	1	2	3,800	3	6,000	27,000
June	..	..	..	.....	..	.....	......	4	1	3	4,000	4	5,750	22,100
July	..	..	..	.....	..	.....	......	5	3	2	3,900	5	8,000	47,700
August	..	..	..	.....	..	.....	......	4	1	3	4,250	4	6,175	43,500
Total (8 mo.)	..	..	..	.....	..	.....	......	28	7	21	30,950	28	46,129	283,500

Steam Jet vs. Other Ash Conveyors

After reading the articles "Steam Jet vs. Vacuum Ash Conveyors," by Eugene Hahn in July issue of COMBUSTION, I believe further information on this subject is not amiss. It has been claimed that the steam jet conveyor is economical, efficient, noiseless, dustless, and compares favorably with any conveyor. This is not the case.

The all important question to be answered in selecting an ash conveyor is "What will it cost over a period of years, in fixed charges, operation and maintenance?" This is not necessarily dependent on simplicity of construction and operation. A low-pressure hand-fired h.r.t. boiler is more simple in construction and operation than the modern high-pressure pulverized-fuel-fired boiler, but no one would expect to go far with hand-fired boilers in competition with modern plants.

A steam jet conveyor pipe is usually laid just below the floor level and in front of the boilers. In front of each ash pit door there is an opening in the pipe which is kept covered except when in use. There is one steam jet for about every 40 ft. of horizontal pipe and one for any normal vertical length. These jets range from 7/16 in. to 5/8 in. in dia. for an 8 in. conveyor pipe, when the steam pressure is 150 lb.

At ash pulling time the jets are turned on, one opening in the conveyor pipe is uncovered, and the fireman starts raking ashes from the pit into the hole, using care not to rake in any large clinkers or slugs of ashes that may clog the pipe at the bend. Meanwhile, from the hole emanates the roar of the jet that makes conversation in that part of the boiler room difficult, to say the least. While the fireman might not care about having a conversation at this time, there might be things happening that he should hear.

Between strokes of the fireman's hoe, the jets blow merrily away doing nothing except scatter the dust at the discharge end of the conveyor, advising the neighborhood that ashes are being pulled, provided they haven't heard the jets. The ash receiver can not be dust tight because of building up back pressure against which the conveyor cannot function. The only solution is a dust eliminator in connection with the receiver, through which the air can pass, but dust cannot. This can be accomplished with a series of baffles and water sprays.

As to efficiency, the steam jet conveyor is comparable with a contrivance for propelling a railroad train through a loosely fitting tube by means of steam jets exhausting against the rear of the train at regular intervals along the length of the tube.

If the jets were located at the terminal end of the tube and exhausted outwardly causing a rush

of air through the tube, this would be comparable with the vacuum system. The principal disadvantage of the vacuum system is the difficulty experienced in keeping the ash receiver air tight. However, if power blowers are used and suitable baffles and sprays are provided to keep the dust from reaching the blowers, it is more efficient than the steam jet system.

The economy of the steam jet system depends to a certain extent on the number of jets, which in turn is dependent on the length of the conveyor pipe, but under very few circumstances is it economical. I have in mind a plant containing six boilers that are served by a three jet ash conveyor. When the pits at the extreme end are being pulled, all three jets are turned on, but after they are finished, only two jets are used. The minimum time for pulling all of them is one hour, and the steam required at 150 lb. pressure and 100 deg. superheat is 5200 lb. The demand varies from 190 b.h.p. when the three jets are on to 145 b.h.p. when only two are on. This is from 10 to 15 per cent of the normal boiler load. Ashes are pulled four times in 24 hours. The cost, at 45 cents per 1000 lb. of steam is $2.34 per pulling of one hour, $2910 per year or $.136 per ton of coal burned. The cost is often increased by having to force the fires in order to carry this extra load. No cost has been added for the hour's hard work of pulling the ashes from the pit into the conveyor intake, nor has any cost been added for extra steam used because of worn nozzles. The above figures were obtained with new nozzles in use.

A bucket or car conveyor will handle the same amount of ashes in half the time with very little labor, and for approximately 10 cents worth of electricity, if it is generated in the plant. There is no disagreeable noise, the ashes can be quenched to any desired extent without plugging any of the mechanism, and no dust eliminator is necessary.

There are many conveyors to choose from, but due to ash removal being an intermittent process and requiring the attendance of one man regardless of what kind of conveyor is in use, it is not justifiable to spend more money than is necessary to get the ashes out in a certain length of time, thereby saving a man's time. A little of his time might be cheaper than fixed charges on elaborate equipment. For instance, it would be cheaper in the long run, to have a track and push car into which to dump the ashes, than it would to have a bucket conveyor extending the length of a long ash tunnel. The car could be dumped into the boot of a skip hoist and the ashes would be removed in a very little longer time than they would have been by the conveyor, and more cheaply.

In the case of an old plant having no ash tunnel and when for some structural reasons it was inadvisable to dig one, the steam jet or vacuum system would be justifiable, but only in such a case.

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